universität wien

MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

„Maternal obesity and its effects on foetal development, neonatal parameters at birth, mode of delivery and miscarriage-rate"

verfasst von / submitted by

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angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien, 2021 / Vienna, 2021

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	UA 066 827
Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet:	Masterstudium Anthropologie
Betreut von / Supervisor:	ao. Univ.-Prof. Mag. Mag. Dr. Sylvia Kirchengast

Acknowledgements

In the course of writing this thesis, I have received support and help. I would like to take this opportunity to thank everyone who has supported me.

First of all, I would like to thank my supervisor Professor Sylvia Kirchengast. She has always given me important food for thought, input and constructive feedback. I would also like to thank her and the Department of Evolutionary Anthropology at the University of Vienna for providing me with the data for this master thesis.

In addition, I would like to thank my colleague and friend Robin Koger for supporting and motivating me in every possible way. With the help of his inputs during numerous discussions I came up with solutions and new ideas.

I would also like to thank my family, especially my parents and brother, who actively supported me throughout my whole studies. Thank you for being there for me all the time.

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Introduction

The number of overweight and obese people is increasing drastically all over the world (WHO, 2020). Obesity is no longer only a problem in developed countries, but is also growing in developing and emerging nations (Ärzteblatt, 2014). For that reason, it is already being considered as an "obesity pandemic". With the increasing numbers of obesity worldwide, a rise in various other diseases associated with obesity is also occurring. Countless studies show that the risk of cardiovascular diseases and various cancers increases significantly with obesity (Lavie & Milani, 2003; Lega & Lipscombe, 2019). In addition, fertility and procreative capacity are affected, in both, men and women (Hammoud et al., 2008; Harreiter & Kautzky-Willer, 2016). Furthermore, the risk of miscarriage increases in obese women (Boots & Stephenson, 2011; Ghimire et al., 2020).

Obesity and overweight during pregnancy have consequences not only for the mother but also for the child. Obesity affects the oxygen supply during birth (Johansson et al., 2018; Persson et al., 2014), the mode of delivery (Kirchengast & Hartmann, 2019; O'Dwyer & Turner, 2012), as well as the new-born parameters (Gaillard et al., 2017; Kirchengast, 2019). Moreover, obesity during pregnancy can also have far-reaching, long-term consequences for mother and child. For example, many studies have shown that there is an increased risk that the child itself will later suffer from obesity (Gaillard et al., 2017).

However, obesity has serious consequences not only for the affected individuals themselves, but also for the healthcare system, the labour market, and thus for each and every one of us (Hackl et al., 2010; Lindeboom et al., 2010). Therefore, there is a major need for action to counteract this pandemic. This requires two steps. On the one hand, the focus should be on preventive measures in order to avoid obesity from occurring in the first place. On the other hand, if obesity is already present, strategies should likewise be developed to ensure healthy, sustainable and long-term weight reduction (Harvard T.H. Chan, 2012). Above all, politicians and decision-makers are called upon to take the right and long overdue measures against the further spread of this disease. After all, obesity kills at least as many people as poverty, smoking and alcoholism. Nevertheless, too little attention is paid to this disease (Sturm & Wells, 2001).

In the context of this master thesis, the focus of the work will be to study the consequences of obesity during pregnancy on mother and child. The aim of this study is to investigate neonatal parameters, as well as birth mode and miscarriage rate in relation to maternal weight status. The next chapter will provide profound background information and an introduction to the topic, presenting previous literature and studies on each topic.

Background information

In order to be able to deal with the complex topic of obesity and pregnancy in more detail, a thorough introduction to the topic is required. Therefore, this chapter will deal with background information on all aspects that will be covered in this master thesis and summarize previous studies and existing literature on the different subchapters. Figures and prevalence of obesity worldwide and specifically in Austria are presented. In addition, the consequences of obesity on fertility are addressed, as well as the possible health outcomes of obesity during pregnancy for mother and child, which can sometimes have far-reaching consequences. Furthermore, the relationship between obesity and mode of delivery is discussed, as well as the risks of oxygen deprivation during birth. In addition, some prevention suggestions are made that would help to reduce this “obesity pandemic”.

Facts and prevalence of obesity

The BMI (body mass index) is a widely used and important way to measure the weight status of adults. The WHO defines overweight as having a BMI above 25 (kg/m^2) and obesity as having a BMI above 30 (kg/m^2). Originally, the BMI was developed to predict the risk of certain diseases that are associated with an increased BMI. These include type 2 diabetes, cardiovascular diseases, hypertension, osteoarthritis, varies forms of cancers, etc. (WHO, 2020).

The prevalence of overweight and obesity is rising dramatically worldwide. According to the World Health Organization, obesity rates have almost tripled in the past 45 years. In 2016, almost 40% of the adult population were overweight and 13% were obese, with an upward trend. By now more people die through overweight and obesity (and the consequences of this disease) than through underweight, although obesity can be prevented (WHO, 2020). The problem of obesity and overweight is no longer limited to industrial nations. The "obesity-pandemic" is just as prevalent in developing and emerging countries (Ärzteblatt, 2014). Mexico for example, with an obesity rate of 32.4% (as of 2014) is one of the countries with the highest obesity rates. In most countries women have higher obesity rates than men, with less educated women at two to three times higher risk than higher educated women (Obesity Update - OECD, 2017).

In Europe the number of obese people has increased in all countries since 2000 as well. The European average of obese adults is 16% in 2014, however there are wide variations within Europe. For example, the obesity rate in Romania is only about 9%, while Malta has an obesity rate of 26% (Health at a Glance, 2018). Austria is about the European average: Overall, about

3.8 million people (out of a total population of 8.86 million, as of 2019) aged 15 years and older are overweight (including obesity). That means that roughly 42.7% of the Austrian population has a BMI over 25 and 16.6% are obese (Statistik Austria, 2020b).

Due to the constantly increasing numbers of overweight and obesity, the costs for the health care system are also growing rapidly. An analysis from Austria shows that obese people cause about 50% higher extramural expenses than people of normal weight do. In addition, the number of average sick days differs between normal-weight and obese persons: normal-weight people have an average of about eight sick days per year. Overweight persons need about 14 days and with obese persons the number of sick days rises already to 21 (Hackl et al., 2010). Thus, it is not too surprising that obese people have greater difficulty finding a job (Hammond & Levine, 2010), as overweight people cost the employer more money in this respect.

Many studies show that overweight and obese people have on average a lower socioeconomic status, mostly measured by their education and income (Lampert, 2010; Marmot, 2005; *Obesity Update - OECD*, 2017). Consequently, this already existing social gap between overweight and normal-weight persons will not decrease, on the contrary: the social gap is increasing. Health inequalities derive from inferior social environment, poor education and poor income (Kelley, 2020). This is a "vicious circle" that cannot be prevented without appropriate countermeasures from policy makers. Since women in most countries are more frequently affected by obesity and thus have a higher risk (Obesity Update - OECD, 2017), and since many of these women are of course of childbearing age, the topic obesity and pregnancy should be examined more closely in order to identify effects of obesity on the new-born child. Therefore, the next chapter discusses trends in obesity rates in women of reproductive age in more detail.

Obesity at reproductive age

In general, it can be said that overweight and obesity rates increase with age. The highest overweight rates in Austria (as of 2019) are in the age group 60-74 years (Statistik Austria, 2020b). Similar figures can be seen in Germany (Gesundheitsberichterstattung des Bundes, 2018). In the U.S., the highest obesity rates are in a younger age category, namely 40-59 years (Hales et al., 2020). Nevertheless, there is an increasing trend of obesity and overweight especially among young adults, people of reproductive age (Anderson et al., 2003). Young people are often faced with major life changes, such as moving, work stress or job changes, personal changes, entering new relationships, etc. (Poobalan & Aucott, 2016). All of these are stressful experiences that can drive up obesity rates. This is especially fatal in women of reproductive age, as overweight and obesity before and during pregnancy is associated with many complications, such as higher caesarean section rates, macrosomia and foetal acidosis, just to name a few (Johansson et al., 2018; Masoud et al., 2016; O'Dwyer & Turner, 2012). This is not only problematic for the women themselves but also for the foetus, or new-born, and the consequences can be far-reaching (Aviram et al., 2011; Gaillard et al., 2013, 2017). A detailed description of the consequences of maternal obesity before and during pregnancy is given in the following chapters.

The number of overweight and obese young women of reproductive age in Austria is steadily increasing, see Figure 1. In 2014, about 13% of 15-29 year olds in Austria were overweight and about 6% were obese, while the numbers increased to 16.1% overweight and 6.7% obese women in this age category by 2019. The trend is similar for women in the 30-44 years age category. In 2014, 21% of women in this age group were overweight and about 8% were obese. In 2019, the numbers increased to 25% and 12%, respectively (Statistik Austria, 2015, 2020b).

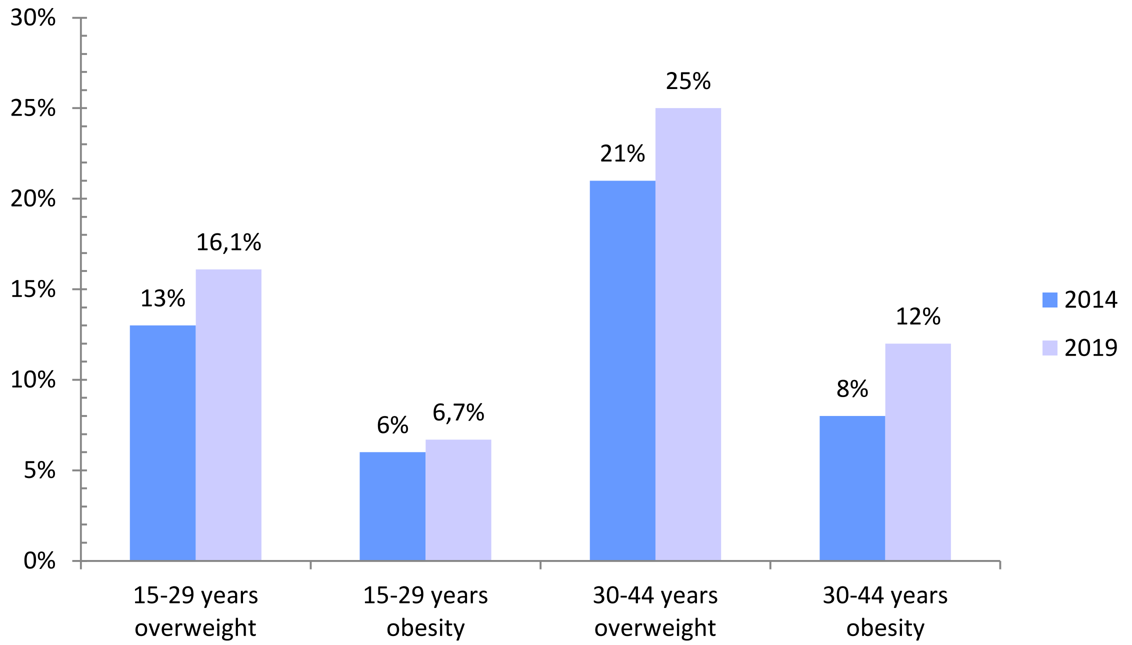

Figure 1: Comparison between the years 2014 and 2019 of overweight and obesity rates among 15-29 years-old and 30-44 years-old in Austria (Statistik Austria, 2015, 2020b)

The figures (as of 2017) in Germany are similar (Gesundheitsberichterstattung des Bundes, 2018). The obesity numbers among young adults in the U.S. are even more shocking. The obesity rate (as of 2017-2018) for women of the age 20-39 years is 39.7% (Hales et al., 2020). In the U.S., a total of two-thirds of women of reproductive age are either overweight or obese and thus have a BMI above 25kg/m² (Hillemeier et al., 2011). There is no question that this confronts us with major challenges, and will continue to do so in the future. Especially for women of reproductive age, this poses a major problem, as overweight and obese women suffer from reduced fertility and miscarriage more often than normal weight women (Brewer & Balen, 2010; Ghimire et al., 2020). This problem will be discussed in more detail in the next chapter.

Reduced Fertility and miscarriages

Although a few studies have not found an association between an increased miscarriage rate and maternal obesity (Risch et al., 1988), most studies do show that obesity correlates with increased miscarriage rates (Boots & Stephenson, 2011; Ghimire et al., 2020; Practice Committee of the American Society for Reproductive Medicine, 2008). It has also been shown that obesity in women is associated with a lower probability of fertilisation, especially in assisted fertilisation, such as in-vitro-fertilisation. In addition, miscarriages are more likely in obese women after assisted fertilisation (Brewer & Balen, 2010).

It has been shown that not only the miscarriage rate is higher in obese women than in women of normal weight, but also that the fertility and the probability to conceive in general are reduced (Brewer & Balen, 2010; Harreiter & Kautzky-Willer, 2016; Practice Committee of the American Society for Reproductive Medicine, 2008). Obese women show a lower probability of fertilisation per cycle. In addition, they show altered hormone balance compared to women of normal weight. As the female cycle is finely regulated, such slight changes in hormone milieu result in cycle irregularities. Increased leptin levels in obese women are also associated with impaired fecundity (Brewer & Balen, 2010).

Although it is not the focus of this study, it should not go unmentioned that male fertility is also negatively influenced by obesity. Overweight and obesity also cause hormonal changes in men which are linked to the degree of obesity. Obese men, for example, show an increase in oestrogen levels and simultaneously a reduction in androgen levels. This leads to a dysregulation of the hormone balance and consequently to an increased probability of altered semen parameters and infertility (Hammoud et al., 2008). In this case, a change in lifestyle towards a healthier way of life is essential to improve the hormone imbalance and thus counteract the higher risk of infertility (Harreiter & Kautzky-Willer, 2016). Considering the many risks associated with obesity in pregnancy, a normal and stable body weight should be achieved before fertilisation, whether natural or assisted, for the good of the woman and the new-born (Brewer & Balen, 2010).

Consequences of obesity during pregnancy for the mother

That pregnancy in obese women is associated with a lot of risks, not only for the mother but also for the new-born, is undisputed. In general, the risk of adverse outcomes during pregnancy increases with the severity of obesity. Even when controlling for sociodemographic status, the results remain the same (Sebire et al., 2001). This chapter will deal with the negative consequences of maternal obesity for the mother that can manifest already during pregnancy or at birth, also long-term consequences cannot be ruled out.

Already early in pregnancy complications can occur in obese women. For example, the risk of gestational diabetes and high or dysregulated blood pressure is greatly increased (Aviram et al., 2011; Edwards et al., 1978; Oteng-Ntim & Doyle, 2012). The reasons for the occurrence of gestational diabetes are not yet fully understood and can be diverse. For instance, visceral fat distribution and an existing family history are discussed as possible causal factors for diabetes during pregnancy. However, great hepatic fat accumulation as well as ethnic origin may also contribute as possible mechanisms for the occurrence of gestational diabetes in obese women (Sattar & Freeman, 2012). The risk of preeclampsia is also greatly increased in overweight and obese women (Bodnar et al., 2005; Motedayen et al., 2019). The underlying reasons are not very clear and more research is needed in this area. Risk factors besides obesity are diabetes and twin pregnancies. In addition, genetic risk factors are assumed to play a role, but this has not yet been completely clarified (Sattar & Freeman, 2012). Furthermore, maternal age, assisted conception and chronic kidney diseases appear to be contributing factors and first-time mothers are also at greater risk of having the disease. Preeclampsia typically develops in the third trimester. It is usually accompanied by sudden appearance of high blood pressure and proteinuria. It should be noted that proteinuria is not an obligatory symptom, which makes the diagnosis somewhat difficult. There may also be a deficiency of thrombocytes, pulmonary oedema and neuro-visual problems (Rana et al., 2019). Preeclampsia is also associated with some long-term sequelae. Thus, women have an increased risk of cardiovascular disease, heart diseases and hypertension (Brouwers et al., 2018; Newstead et al., 2007). Women who are at increased risk, especially obese women, should therefore be regularly examined with special attention as there is no direct prevention of this disease (Trogstad et al., 2011). Whether there are other long-term effects of obesity during pregnancy for the mother is not yet fully understood. While it is clear that obesity in general is associated with many negative diseases, more studies are needed to understand the possible relationship between pregnancy, obesity and long-term effects for the mother (Deierlein & Siega-Riz, 2012).

Mental health during pregnancy can also be affected by obesity. Studies have shown that pregnant women who struggle with mental health are more likely to be obese than women without mental-health problems (Howard & Croker, 2012). This is essential because due to psychological disorders and mental health problems during pregnancy not only the mother but also the child suffers. Physical health is ensured only when mental health is maintained (Howard, 2005).

It has often been shown that obesity in women is associated with an increased rate of caesarean deliveries (Kirchengast & Hartmann, 2019; Masoud et al., 2016; O'Dwyer & Turner, 2012). Not only does this cause medical complications and potential risks, but caesarean sections in morbidly obese women are also technically difficult to perform. Obese women are more difficult to transport or to lift up, sometimes require special operating tables and the surgery itself is also riskier, for example, regarding infections (O'Dwyer & Turner, 2012). In addition, maternal obesity is associated with difficulties during delivery, respiratory problems and thrombosis, to mention just a few other examples (Aviram et al., 2011).

The negative effects of obesity during pregnancy are without doubt. For both the child and the mother, these pregnancies are a major risk-factor that can have long-lasting consequences. The question arises which measures must be taken to reduce the obesity rates in women of childbearing age and thus minimize the risks of adverse pregnancy outcomes and potential long-term consequences for mother and child. Weight loss before or at the latest early in pregnancy is strongly advised in obese women, but diets or medical interventions are not recommended as they could be potentially harmful (Aviram et al., 2011). Instead, in addition to a balanced and healthy nutrition, sports and physical activity should be considered. It has been shown that regular exercise in obese pregnant women leads to a reduction in the prevalence of gestational diabetes mellitus (Dye et al., 1997).

Consequences of obesity during pregnancy for the child

Pregnancies in obese women are considered high-risk pregnancies. However, there is not only a risk for the mother but also for the child. The consequences can be short-term as well as long-term. Hereafter, the consequences of a high BMI of the mother before pregnancy and large gestational weight gain during pregnancy for the child will be discussed.

It has been shown that the consequences of maternal obesity for the new-born can already occur during pregnancy or immediately after birth. Studies have shown that obesity during pregnancy dramatically increases the risk of infant mortality and stillbirth (Chu, Kim, Lau, et al., 2007; Lindam, 2016). In addition, new-borns of obese mothers have an increased risk of congenital defects. These include, for example, spina bifida, cleft lip and palate, hydrocephalus and heart defects such as septal anomalies (Marchi et al., 2015; Stothard et al., 2009). In general, there is an increase in the risk of low APGAR score with maternal obesity (Zhu et al., 2015). In addition, maternal obesity and severe weight gain during pregnancy are also associated with macrosomia (Jolly et al., 2003; Kirchengast, 2019). Head circumference as well as birth length are also significantly larger in new-borns of overweight and obese mothers than in normal-weight women (Athukorala et al., 2010). In addition, the risk of (induced) preterm birth increases in obese and overweight women. As a result, infant mortality is increased and the risk of long-term retardation in the new-born increases (Schummers et al., 2015; Smith et al., 2007).

However, complications can occur not only immediately after birth in children of obese mothers, but the consequences can extend well into childhood or even adulthood. Maternal obesity and severe weight gain during pregnancy are both associated with an increased risk of being overweight or obese during childhood (Fraser et al., 2010; Schack-Nielsen et al., 2010). But it is not only the child's cardiovascular system that is affected by maternal obesity during pregnancy. Some studies suggest that there is an association with cognitive abilities of the child (Basatemur et al., 2013; Sanchez et al., 2018). These results remain when controlling for sociodemographic factors (Basatemur et al., 2013). In addition, the results of some studies suggest that in children of obese mothers there is an increased risk of autism spectrum disorder (Li et al., 2016) and a high BMI before pregnancy has also been associated with ADHD (=Attention Deficit Hyperactivity Disorder) symptoms in the off-spring (Rodriguez et al., 2008). However, it should be noted that the results of some studies on cognitive performance are inconsistent, thus further research in this area is needed (Gaillard et al., 2017). Another long-term consequence of maternal obesity during pregnancy for the child is that the respiratory system might be affected. Forno et al. (2014) found that maternal obesity before pregnancy and a severe gestational weight gain increase the risk for asthma in the child. In addition, the children of obese mothers suffer from wheezing more often than children of normal weight women (Zugna et al., 2015).

It needs to be clarified whether the causes of the negative consequences of maternal obesity for the child actually have a biological, intrauterine origin or are more likely to be explained by environmental or socioeconomic parameters. For this purpose, it must be checked whether maternal obesity alone leads to such associations or whether paternal obesity has the same or similar effects (Gaillard, 2015). However, various actual biological, intrauterine causes of the consequences of maternal obesity on the child could be shown by previous studies. For example, epigenetics play a role in this case, with the child's organism being incorrectly adapted to the later environment (Hanson et al., 2011). In general, children with higher birth weights also show a tendency to have an increased risk of overweight and obesity later in life (Yu et al., 2011). Another mechanism that may be involved is that specific tissues, like fat cells, pancreatic cells and muscle cells in the child's organism are altered by maternal obesity (Drake & Reynolds, 2010). In fact, the hormonal balance of obese mothers is different from that of normal-weight mothers. Especially the hormones leptin and insulin play a role in this case. It has been shown that this leads to a change in hypothalamus gene expression which can lead to an altered sensation of appetite (Glavas et al., 2010; Patel & Srinivasan, 2010; Poston, 2012). However, the underlying biological reasons for these consequences are not yet fully understood and more research in this direction is needed.

Because pregnancy in obese women can have such far-reaching and long-term consequences for the child, it is even more important to understand and address the issue in depth. Obesity during pregnancy is associated with many negative health consequences for the child; however, obesity is preventable. Women should be supported, in their own interest, in the interest of their children and in the interest of the health care system, to avoid obesity already before pregnancy in order to prevent possible fatal consequences that can result from it. Public awareness measures must be taken and the possible consequences must be clearly communicated in order to prevent obesity in pregnancy in the best possible way. This is where politicians and decision-makers are urged to act.

Effects of obesity on the mode of delivery

There is no dispute that maternal obesity can have an impact on both mother and child with long-term consequences. In fact, also the mode of delivery and the risk of caesarean section are associated with maternal obesity. The following chapter addresses the increasing numbers of caesarean sections worldwide, the association of maternal obesity with the mode of delivery, as well as risks and consequences that may accompany it.

The WHO recommends a caesarean section rate of no more than 10 to 15% of all births (WHO, 1985). However, this guideline value is far from being met. Only 14 countries worldwide meet this recommendation. In 2008, 54 countries had a caesarean section rate under 10% while 69 countries had a rate over 15% (Gibbons et al., 2010). It could be estimated that 3.18 million additional caesarean sections would have been necessary in 2008, while in that year also 6.2 million "unnecessary" (i.e. not medically necessary) caesarean sections were performed. This not only represents the inequality of access to medical treatment worldwide, but also the costs associated with it are enormous. It is estimated that worldwide 2.32 billion US dollars are spent annually on medically unnecessary caesarean sections, while only a fraction of this, namely 432 million US dollars, would those caesarean sections cost that would actually be additionally necessary (Gibbons et al., 2010).

In Austria, 30.1% of babies were delivered by caesarean section in 2019, with 16.6% being planned caesarean sections and 13.5% unplanned (Statistik Austria, 2020a). This causes an estimated annual cost of over 8.5 million Euros in Austria (Gibbons et al., 2010).

However, not only are the numbers of "unnecessary" caesarean sections increasing, but also those that are actually medically necessary. There are many reasons for this. On the one hand, it has been argued that the secular trend in body height due to improved conditions results in the foetus being disproportionately large, since it is one generation after the mother (Zaffarini & Mitteroecker, 2019). On the other hand, current developments of lifestyles also lead to an increase in the rate of caesarean sections. For example, older maternal age, smoking during pregnancy and obesity are risk factors that further increase the rate of actually medically necessary caesarean sections (Kirchengast & Hartmann, 2019).

Many studies, like Masoud et al. (2016), have already shown that maternal obesity plays a special role in the caesarean section rate. The biological causes of the increased caesarean section rate in obese women are not yet fully understood. In general, obese women are high-risk patients. Therefore doctors tend to opt for a caesarean section rather than a vaginal delivery. However, if biological reasons alone are considered, there are also some factors that can explain the increase in the caesarean section rate. Some assume that the biological reasons lie in the increased amount of fatty tissue near the pelvis in obese women. This causes the birth canal to narrow and increases the risk of head-pelvis disproportion (Chu, Kim, Schmid, et al., 2007). In addition, maternal obesity increases the risk of macrosomia (Jolly et al., 2003), regardless of whether or not the mother also has gestational diabetes (Kirchengast, 2019). Macrosomia, in turn, increases the risk of caesarean section (Araujo Júnior et al., 2017). A difference in birth process, contractions and response to oxytocin in obese women is also discussed as possible cause for the increased risk of caesarean delivery in obese women (Chu, Kim, Schmid, et al., 2007).

Since maternal obesity has a strong influence on the mode of delivery and consequently has an impact on the woman, the child, the treating physicians and thus also on the health care system, this subject will also be addressed in this master thesis. The aim is to clarify the current situation in Austria, to what extent maternal obesity affects the mode of delivery and whether and how much the risk of caesarean section is increased in obese women compared to women of normal weight.

Oxygen deficiency during birth

Although neonatal healthcare has now reached an extremely good level, oxygen deficiency during birth remains a major problem for the neonate, which can cause many acute problems as well as long-term sequelae (Alonso-Alconada et al., 2015). Worldwide, asphyxia is one of the largest direct causes of neonatal death, after preterm-births and severe infections. It is responsible for 23% of neonatal deaths (Lawn et al., 2005). Oxygen deprivation during birth is associated with many negative effects for the neonate, the brain being damaged the most. Perinatal asphyxia is associated with cerebral disorders and thus increases the risk for abnormal neurological development, as well as hypoxic ischemic encephalopathy (Goodwin et al., 1992). Long-term consequences of oxygen deprivation can be cerebral palsy, a spastic dysfunction of locomotion (Malin et al., 2010). In addition, oxygen deprivation increases the risk for seizures in neonates (Williams & Singh, 2002) and even is a major risk factor for early neonatal death (Heller et al., 2003). In addition, many survivors have difficulty with learning later in life and often exhibit epilepsy or other cognitive and behavioural problems (Alonso-Alconada et al., 2015).

The underlying reasons for severe oxygen deficiency during childbirth can be complex and diverse. Occasions resulting in acute foetal asphyxia are umbilical cord prolapse, rupture of the uterus and amniotic fluid embolism. In addition, a sudden drop in the mother's heart rate and cardiac output, for example due to heavy bleeding or allergic reactions, can lead to an insufficient supply of oxygen to the foetus (Alonso-Alconada et al., 2015). Risk factors for oxygen deprivation can be divided into two categories: those that occur before birth and those that occur during birth.

Risk factors that occur during childbirth are, according to Badawi et al. (1998b) maternal pyrexia, an emergency caesarean section as well as surgical vaginal delivery. In addition, the position of the child in the womb plays a role. An occipitoposterior position/breech presentation can also be a risk factor for oxygen deficiency (Badawi et al., 1998b). However, risk factors can already occur before and during pregnancy. Antepartum risks include maternal age, with older mothers being at greater risk. Genetic factors and an existing family history also play a role, as do thyroid disorders and viral infections during pregnancy (Badawi et al., 1998a). Other risk factors are inexperienced obstetricians and no adequate screening during pregnancy (Butt et al., 2008). Preeclampsia can also lead to hypoxia and thus to neurological damage in the foetus (Aslam et al., 2014). A number of studies have already shown that the risk of preeclampsia increases with BMI (Bodnar et al., 2005; Motedayen et al., 2019; Trogstad et al., 2011), which shows again how far-reaching the consequences of obesity during pregnancy are. Hence obese women belong to the risk group. They should be thoroughly screened during pregnancy to identify preeclampsia as early as possible and to minimize the consequences of preeclampsia for mother and child. Previous studies have shown that the risk of foetal acidosis and related adverse outcomes was increased in new-borns of overweight or obese women (Johansson et al., 2018; Persson et al., 2014). Even when controlled for diabetes, or other obesity-associated diseases, the risk was still increased. This suggests that obesity is an independent risk factor.

The question arises of how to quantify oxygen deficiency in the new-born in order to be able to take appropriate measures. The APGAR score is most often used as an indicator of the new-born's health status. For the calculation of the APGAR score, physical appearance, pulse, reflexes, muscle tone and respiration are used (Apgar, 1953). If the score is low, this may indicate a lack of oxygen during birth. Nevertheless, the APGAR score is a subjective assessment of the respective doctor, thus intra- and inter-observer reliability is variable and results are not consistent between different doctors. An accurate, reproducible and objective evaluation of the oxygen deficiency during birth using the pH value of the umbilical cord blood is therefore recommended to evaluate the new-born outcome (Mogos et al., 2019). The determination of the pH-value can help to decide whether a further supply of oxygen is useful for the new-born (Uslu et al., 2012). Since perinatal asphyxia can have a huge impact on the new-born with long-term consequences, this study will address this issue in more detail. The aim is to clarify the extent to which the risk of oxygen deficiency during birth increases in obese mothers.

Obesity prevention: what still needs to be done

Obesity and overweight exist all over the world and have become a pandemic that has spread throughout the world over the last few decades. The consequences of this pandemic are fatal for each individual affected, for the healthcare systems and for society as a whole. The even more shocking thing is that it does not only affect the person him- or herself, but also the next generation (which actually cannot do anything about it) is affected by this pandemic via both socio-economic and biological parameters. Two steps are therefore absolutely necessary. On the one hand sufficient preventive measures must be taken to prevent obesity from the very beginning, and on the other hand, if obesity already exists, appropriate interventions must be made to reduce it, minimize it and return to a healthy weight. The following chapter will therefore discuss recommendations for obesity prevention and “sustainable” weight loss.

First, it is important to look at the pandemic in the big picture and not focus on individuals. In order to sustainably reduce the numbers of obesity and fight the pandemic, the issue of obesity should be considered at all levels. In other words, action should be taken not only at the individual level or within the family, but should be discussed more broadly: At school, at work, among friends, in the neighbourhood, in the city, in the country and across countries. The issue must be addressed at all instances, by government and non-governmental organizations (Harvard T.H. Chan, 2012).

Second, it is important to understand that the obesity pandemic is not due to a lack of willpower or craving, but has deeper causes. In the 1960s, Neel developed the "Thrifty gene hypothesis" in an attempt to explain the increasing prevalence of obesity and diabetes mellitus (Neel, 1962). His suggestion was that during the evolution of humans, those genes that were responsible for efficient fat storage established, as humans used to struggle regularly with starvation periods. Today, these genes turn out to be disadvantageous, because humans do not need to struggle with famines any more, on the contrary: we are living in times of abundance. So basically he suggested that we are dealing with a mismatch, a heritage from earlier times. Although the hypothesis has been criticized several times, e.g. by Speakman (2008), it still suggests the importance of the role of evolution, adaptation, and heredity in this case and that the expansion of the obesity pandemic did not result from a lack of willpower of the individuals.

Only then, after understanding the underlying reasons for the pandemic and its extent, in the third step, the possible measures from the political side can be discussed. Yet what could such political countermeasures look like? What are the strategies for effectively and sustainably containing the "obesity pandemic"? To prevent and reduce obesity significantly, some authors recommend measures like labelling unhealthy food in grocery stores and restaurants and gaining attention in media and social media to create awareness. They suggest a stricter regulation of advertising unhealthy food to protect children in particular (Obesity Update - OECD, 2017). Information fliers and posters could help in rising awareness as well, since they have a large range. However, the question arises how effective these are, since they are in direct "competition" with posters of fast food chains (Hackl et al., 2010).

Of course, the diet of children is strongly dependent on the diet of their parents and family. Eating fruits and vegetables plays a special role in preventing and reducing obesity. It should be noted that the consumption of fruits and vegetables depends on their availability at home (Jago et al., 2007). This is where socioeconomic status comes into play again, as food choices are highly dependent on social class. Higher quality products, such as whole grains or fresh fruits, are more likely to be consumed by people of higher socioeconomic status. This is again determined by the price and availability of the products (Darmon & Drewnowski, 2008). Extremely important therefore is the determination of the price of all kinds of food. This has to be done centrally by the government. Studies have shown that the price of certain foods can have a major influence on whether and how often these foods are consumed. It was shown that lowering the price of sodas and pizzas led to an increase in calorie intake and weight gain (Duffey et al., 2010). In addition, a higher price of fruits and vegetables resulted in increased caloric intake and ultimately in obesity (Sturm & Datar, 2005). Other regulations such as banning the selling of soft drinks at schools and a consumption tax on unhealthy, particularly sugary food are also discussed and are already being implemented by some countries, like the UK (Grogger, 2017; the global diabetes community, 2019). The environment in which one grows up and lives certainly has a great impact on nutrition. It is fair to say that our environment determines what ends up on our plates every day. There is also a need for action in schools and at workplaces, as the food in canteens or in restaurants nearby unfortunately does not provide a balanced and healthy diet in many places (Shimotsu et al., 2007).

These measures are all useful and important, but obesity prevention should start even earlier. More precisely, appropriate measures by parents should be already taken in infancy. It has been shown that sufficient sleep in infants reduces the risk of obesity in preschool children (Taveras et al., 2008). It has also been shown that the longer children are breastfed, the lower the risk for obesity (Harder et al., 2005).

Just as important as taking preventive measures is the developing of strategies for reducing existing obesity and achieving long-term weight loss. This is important for all age groups, but especially important for women of reproductive age, as the consequences of obesity during pregnancy can be fatal for both mother and child. Obesity is a chronic disease and should be considered and treated as such (Semlitsch et al., 2019). It is important to understand that reducing obesity requires a lot of help from different professionals. Only very few obese people manage to sustainably lose a lot of weight by their own. To reduce severe obesity a program of dietary, habitual and lifestyle changes is needed. This program should be followed for at least six to twelve months, with a calorie deficit, increased physical activity and behavioural changes in daily life and diet as the primary goals. Only when all non-invasive methods of weight reduction have failed, surgical intervention can be discussed. This should only be carried out if the BMI is above 35 kg/m^2. After this kind of surgery regular check-ups should be performed in the long term (Semlitsch et al., 2019).

Limiting sedentary activities in everyday life also plays an important role in weight reduction. Many people spend most of their time, whether at work or at school, sitting in front of a computer screen. Even after work or school sedentary activities often predominate. It has been shown that reducing additional “screen time” can lead to more exercise and better nutrition, which helps reducing overweight and obesity (Buchanan et al., 2016). Stress also has a huge impact in weight loss. Many studies have already looked at the influence of stress on dietary behaviour. It has been shown that increased stress causes people who are not hungry to continue eating anyway (Lemmens et al., 2009).

In conclusion, the prevention of obesity and the reduction of weight in general are very complex issues. It is important to understand that obesity has a complex, biological and evolutionary basis and that the responsibility does not lie solely with the individuals themselves. Advertising, lifestyle and prices of foods and groceries have a huge impact on what is consumed, by whom and how much. There is still a lot of work to be done by policymakers to reduce obesity on a larger scale and thus to reduce the burden not only on the individuals themselves, but also on the healthcare system and thus on each and every one of us. However, although the government and the political system bear a major role in preventing and combating the obesity epidemic, ultimately it remains up to oneself to realize the problem, accept help and make healthy choices.

Research questions

This work focuses on the question of the effects of maternal obesity before and during pregnancy on new-borns. More precisely, maternal weight classes defined by the WHO using the body mass index (WHO, n.d.) are used to explain differences in neonatal parameters. As neonatal parameters, which to some extent also reflect foetal development, the birth length, birth weight and head circumference of the new-borns are used. In addition, the question arises what risks obesity can bring during childbirth. The purpose is to show whether and how severe the oxygen deprivation during birth is for the new-born of an obese woman compared to the new-born of a normal weight woman. Another important aspect is to clarify to what extent the mode of delivery is influenced by maternal weight. Finally, it will be shown how maternal weight affects the history of miscarriage rate.

As these issues become more relevant due to the rising obesity rates, it is especially important to pay sufficient attention to these questions. Obesity during pregnancy not only places a short-term burden on the health care system, but can have long-term impacts, as the consequences of obesity during pregnancy can have long-lasting effects on both mother and child. Dealing with this issue now can have a major impact on the next generation. In the following chapter, the hypotheses that will be addressed in this master thesis are defined in more detail.

Hypotheses

Three hypotheses will be tested in this master's thesis. The first hypothesis is further divided into three sub-hypotheses. The first two main hypotheses concern neonatal parameters. The aim is to find out whether and to what extent maternal obesity directly affects the new-born. The third hypothesis focuses on the mother. The consequences of maternal obesity on miscarriage rates as well as on birth mode will be investigated.

Hypothesis 1: Neonatal parameters differ between children of normal weight and obese women.

a. Children of obese women have on average higher birth weights than children of normal weight women.
b. Children of obese women have on average higher birth lengths than children of normal weight women.
c. Children of obese women have on average higher head circumferences than children of normal weight.

Hypothesis 2: The children of obese women suffer a longer lack of oxygen during childbirth than the children of normal-weight women (indicator: pH value of the umbilical cord blood).

Hypothesis 3: Women who are overweight or obese at the time of data collection have a higher history of miscarriages (indicator: difference of gravida and para) and birth modes differ between normal-weight and obese women.

Material and Methods

Sample

The sample includes births from 15405 women. The women in this sample range in age from 13 to 45.5 years; the average age is 30 years. The overall average BMI of the women in this sample is 24.08 kg/m². All births are singleton births. Twin births and stillbirths are excluded from this sample. Deliveries took place at a public hospital in Vienna (Sozialmedizinisches Zentrum Ost – Donauspital). The data have been collected from 2009 to 2019.

Data acquisition

The new-born parameters were determined directly after birth by a midwife, or if necessary by a neonatologist. Maternal parameters, on the other hand, were recorded by a doctor at the first screening visit.

New-born parameter

Neonatal parameters include birth weight (in grams), birth length (in cm), and head circumference (in cm). In this study, macrosomia is defined as a birth weight greater than 4000g. In addition, the natal position is documented. The pH value of the arterial and venous umbilical cord blood is measured to one decimal place. Only births that meet the following criteria are included in the cord blood analysis: merely cases where the pH value is above 6.4 are included in the analysis. Furthermore only primiparous women and only vaginal births after the 37th week of pregnancy (i.e. no premature births) are taken into account.

Maternal parameter

The maternal parameters of this analysis include maternal age (in years, specified to months), body height (in cm) and body weight at the beginning and at the end of pregnancy (in kg). The corresponding weight gain in percent of body weight is also calculated. In addition, the prepregnancy BMI (kg/m²) is calculated and classified into the following categories according to WHO criteria (WHO, n.d.):

table 1: Weight status based on BMI according to WHO. Obesity is divided into two subcategories: Obesity is defined as a BMI of 30.0 to 39.9 kg/m² and morbid obesity is defined as a BMI of 40 kg/m² or more.

Maternal weight class	**BMI (kg/m²)**
underweight	< 18.5
normal weight	18.5–24.9
overweight	25.0–29.9
obesity	30.0-39.9
morbid obesity	>40

In addition, the duration of pregnancy (in weeks, since the last menstrual period) is documented. A preterm birth is defined as a birth at less than 37 weeks of gestation. Information about the number of pregnancies as well as the number of actual births is provided. Additionally, mode of delivery is documented, distinguishing between four categories: spontaneous vaginal delivery, assisted vaginal delivery (forceps delivery or VE=vacuum extraction), primary caesarean section and secondary caesarean section. No data on education level, marital situation, income, profession or socioeconomic status is collected.

Statistical analysis

The statistical analysis is carried out with IBM SPSS version 27. The significance-level is set to 0.05. First, the data is analysed descriptively. Kruskal Wallis *H* tests are performed to test for differences in neonatal and maternal parameters between maternal weight classes. Bonferroni post hoc tests are then conducted to allow pairwise comparisons between all groups. To evaluate the risk of macrosomia, the risk ratios are calculated for each maternal weight class compared to the normal weight women with the respective 95% confidence interval.

To test for an association between maternal BMI and pH values of the arterial and venous umbilical cord blood, linear regressions and Kruskal Wallis *H* tests are calculated. Bonferroni corrections are then applied to allow pairwise comparisons between the groups.

The difference between the number of previous pregnancies and the number of births was used as an indicator of the miscarriage rate. To test for an association between maternal weight class and miscarriages, a Pearson Chi² test is performed. In addition, the risk ratios for miscarriages are calculated for each maternal weight class compared to the normal weight women with the respective 95% confidence interval. A Kruskal Wallis *H* test followed by a Bonferroni correction is carried out to test for a difference in the number of miscarriages between maternal weight classes.

To determine the association of birth mode with maternal weight status, a Pearson Chi² test is applied. The relative risk of a secondary caesarean section is calculated for each weight category compared to normal weight women. Binary logistic regression is used to calculate the effect of maternal weight class on mode of delivery, independent of weight gain during pregnancy, maternal age and body height.

Results

Sample description

A detailed description of the maternal and new-born parameters of this sample is shown in table 2. The average age of the mother is 30.0 years and the average height is 165.4 cm. The average weight before pregnancy is 66 kg and 80 kg at the end of pregnancy. On average, the women in this sample gain 22.4% of their pre-pregnancy body weight during pregnancy. 952 women (corresponding to 6.2%) in this sample have a BMI less than 18.50 kg/m² and 61.0% of the sample have a BMI in the recommended range of 18.50 to 24.99 kg/m². 20.5% have a BMI between 25 and 29.99 kg/m², 10.7% have a BMI between 30 to 39.99 kg/m² and 1.2% have a BMI greater than 40 kg/m². The average birth weight in this sample is 3385.6 g, the average birth length is 50.6 cm and the average head circumference is 34.2 cm.

table 2: overview of the maternal and new-born parameters of the sample

Maternal parameters	**Mean (SD)**	**Range**	***N***
age (years)	30.0 (5.6)	13.0-45.5	15405
stature (cm)	165.4 (6.3)	140-193	15405
pre-pregnancy weight (kg)	66.0 (14.4)	35-162	15400
end of pregnancy weight (kg)	80 (14.6)	43-172	14406
gestational weight gain (%)	22.4 (10.4)	-30-84.8	14403
gestational weight gain (kg)	14.0 (6.0)	-30-43	14403
pre-pregnancy body mass index (kg/m²)			
< 18.50 kg/m²			952 (6.2%)
18.50 – 24.99 kg/m²			9398 (61.0%)
25.00 – 29.99 kg/m²			3160 (20.5%)
30.00 -39.99 kg/m²			1653 (10.7%)
≥40 kg/m²			190 (1.2%)
New-born parameters	**Mean (SD)**	**Range**	***N***
birth length (cm)	50.6 (2.6)	28.0-56.0	15382
birth weight (g)	3385.6 (540.0)	470-5350	15405
head circumference (cm)	34.2 (1.7)	21.5-53.0	15375
pH value (arterial cord blood)	7.3 (0.1)	6.5-7.7	5554
pH value (venous cord blood)	7.3 (0.2)	6.9-7.7	5470

Comparison of maternal and new-born parameters between weight classes

To evaluate for possible differences in maternal and neonatal parameters between the pre-pregnancy maternal weight-classes, Kruskal-Wallis H tests and post hoc tests according to Bonferroni are conducted to allow pairwise comparison between all groups, see table 3.

The following new-born parameters are analysed and compared between the weight classes: Head circumference, birth weight and birth length. With increasing maternal weight class, the birth lengths become greater ($H = 155.838$, $p<0.001$). Post-hoc tests show that only the birth lengths of the new-borns of normal-weight women and overweight women do not differ significantly, while there are significant differences between all other pairwise group comparisons. Birth weight also shows significant differences between the groups (H = 298.536, p<0.001) with a tendency for birth weight to increase as the mother's BMI increases. Pairwise comparisons show that the birth weights of the children of underweight and normal-weight women are each significantly different from every other group. Within the overweight, obese and morbid obese women, however, no significant birth weight differences can be detected. Head circumference also shows significant differences between the groups (H = 137.680, p<0.001), in which the baby's head circumference tends to increase as the mother's BMI increases. More precisely, the head circumference of children of underweight women is significantly smaller than in all other groups and the head circumference of children of normal weight women is significantly smaller than that of children of overweight and obese women.

For maternal parameters, age, height and gestational weight gain as a percentage of pre-pregnancy body weight are compared between groups. The maternal age differs significantly between the groups (H = 122.192, p<0.001). Subsequent post-hoc tests show that only the underweight women differ significantly in age from the other groups, with the underweight mothers being on average two years younger than those in the other groups. Significant differences between the groups can also be recognised with regard to stature (H = 20.533, p<0.001). However, only the overweight and underweight women differ significantly in terms of body height, with the underweight women being on average taller than the overweight women. With regard to gestational weight gain, there are also significant differences between the groups (H = 3609.038, p<0.001) with the percentage decreasing with increasing weight class. Here, each group differs significantly from every other group.

table 3: Wallis H test (and Bonferroni corrections) and comparison of maternal and new-born parameters among the weight classes Significance levels: ***p<0.001, **p<0.01, *p<0.05

		Maternal parameters				New-born parameters		
weight categorie		Age (years) [a,b,c,d]	Stature (cm) [b]	Prepregnancy weight (kg)	Weight gain (%) [a, b, c, d, e, f, g, h, i, j]	Birth length (cm) [a, b, c, d, e, g]	Birth weight(g) [a, b, c, d, e, f, g]	Head circumference (cm) [a, b, c, d, e, f]
Under-weight BMI<18.5	*N*	963	936	963	895	961	963	958
	Mean	28.1	165.7	48.5	30.7	50.0	3177.8	33.8
	SD	5.9	6.2	4.4	11.6	2.3	498.0	1.5
	Median	27.6	165.0	49.0	28.9	50.0	3180.0	34.0
	Q1/Q3	23.7/32.1	162.0/170.0	45.0/51.0	23.2/36.2	49.0/51.0	2880.0/3490.0	33.0/35.0
Normal weight BMI 18.5-24.9	*N*	9398	9398	9398	8781	9384	9398	9383
	Mean	30.0	165.6	59.6	25.0	50.6	3370.1	34.2
	SD	5.5	6.3	6.4	9.2	2.5	516.4	1.6
	Median	30.0	165.0	59.0	24.5	51	3390.0	34.0
	Q1/Q3	26.1/33.8	161.0/170.0	55.0/64.0	18.7/30.5	50.0/52.0	3080.0/3700.0	33.0/35.0
Over-weight BMI 25-29.9	*N*	3160	3160	3160	2959	3155	3160	3153
	Mean	30.3	165.1	74.1	18.3	50.8	3443.9	34.3
	SD	5.6	6.4	6.9	8.4	2.7	561.4	1.8
	Median	30.2	165.0	74	17.6	51.0	3470	34.0
	Q1/ Q3	26.3/34.1	160.0/170.0	70.0/79.0	12.5/23.4	50.0/52.0	3140.0/3780.0	33.0/35.0
Obesity BMI 30-39.9	*N*	1653	1653	1653	1553	1651	1653	1650
	Mean	30.3	165.1	90.9	12.1	50.8	3471.5	34.4
	SD	5.5	6.2	10.2	8.0	2.8	604.5	1.8
	Median	30.3	165	90	11.8	51.0	3510.0	34.0
	Q1/ Q3	26.2/34.3	160.0/170.0	84.2/97.5	7.2/16.6	50.0/52.0	3130.0/3850.0	33.0/35.0
Morbid obesity BMI >40.0	*N*	190	190	190	181	190	190	190
	Mean	30.5	166.3	119.8	6.1	51.0	3490.7	34.5
	SD	5.4	5.8	12.4	6.1	2.3	573.5	1.8
	Median	30.5	167	119.0	6.2	51.0	3495.0	34.0
	Q1/ Q3	26.6/34.5	162.7/170.0	110.0/126.0	2.1/9.1	50.0/52.0	3125.0/3882.5	34.0/36.0
***H*- test**	*H*	122.192***	20.533***	/	3609.038***	155.838***	298.536***	137.680***

Dunn-Bonferroni Post-hoc test:

[a]= sign. difference between the categories 1 and 2
[b]= sign. difference between the categories 1 and 3
[c]=sign. difference between the categories 1 and 4
[d]= sign. difference between the categories 1 and 5
[e]= sign. difference between the categories 2 and 3
[f]=sign. difference between the categories 2 and 4
[g]= sign. difference between the categories 2 and 5
[h]= sign. difference between the categories 3 and 4
[i] =sign. difference between the categories 3 and 5
[j]= sign. difference between the categories 4 and 5

Figure 2, Figure 3 and Figure 4 illustrate the distribution of the new-born parameters across mother's weight classes. Figure 2 shows that medians and quartiles of birth weights increase with increasing maternal weight class. Only new-borns of morbidly obese women have slightly lower birth weights compared to those of obese women. Thus, birth weight increases from 3180g in children of underweight women to 3510g in obese women. Looking at birth length, some differences in medians and quartiles can also be observed: Children of underweight women have a birth length of 50cm (Q1/Q3=49/51 cm), while the medians for all other groups are 51cm (Q1/Q3=50/52 cm), see Figure 3. Regarding the new-borns head circumference, only the quartiles of children of morbidly obese women distinguish from all other groups, showing higher scores on quartiles, see Figure 4.

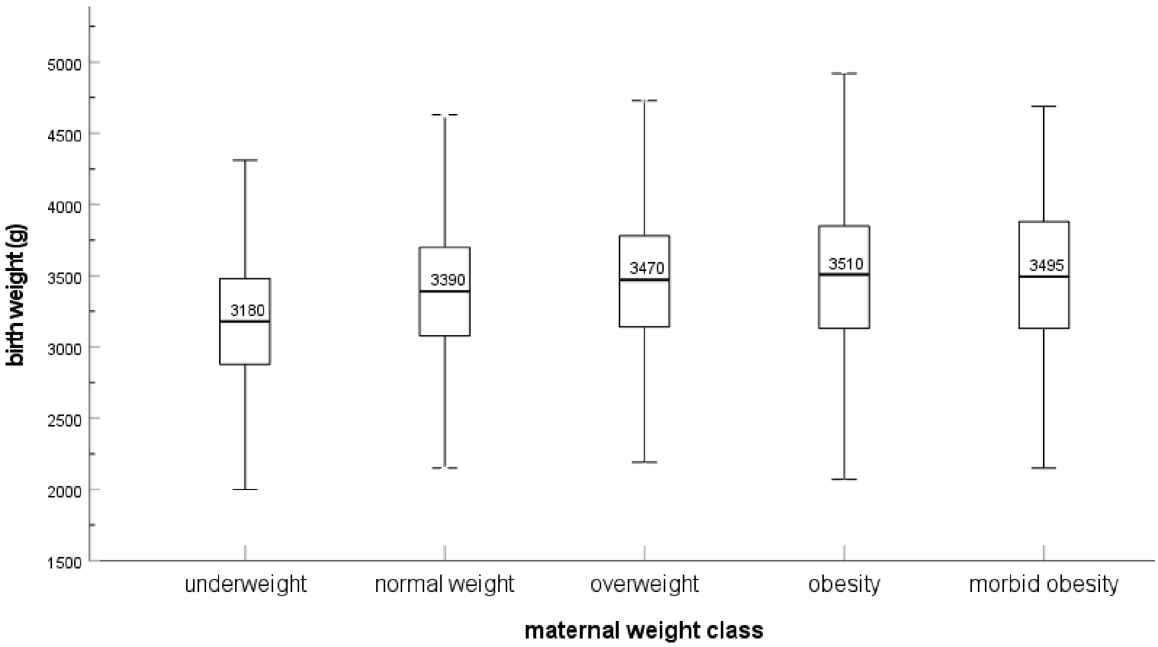

Figure 2: Boxplots of birth weights in each maternal weight class. The outliers and extreme values are not shown. Birth weight increases with increasing maternal weight class and decreases slightly with morbid obesity

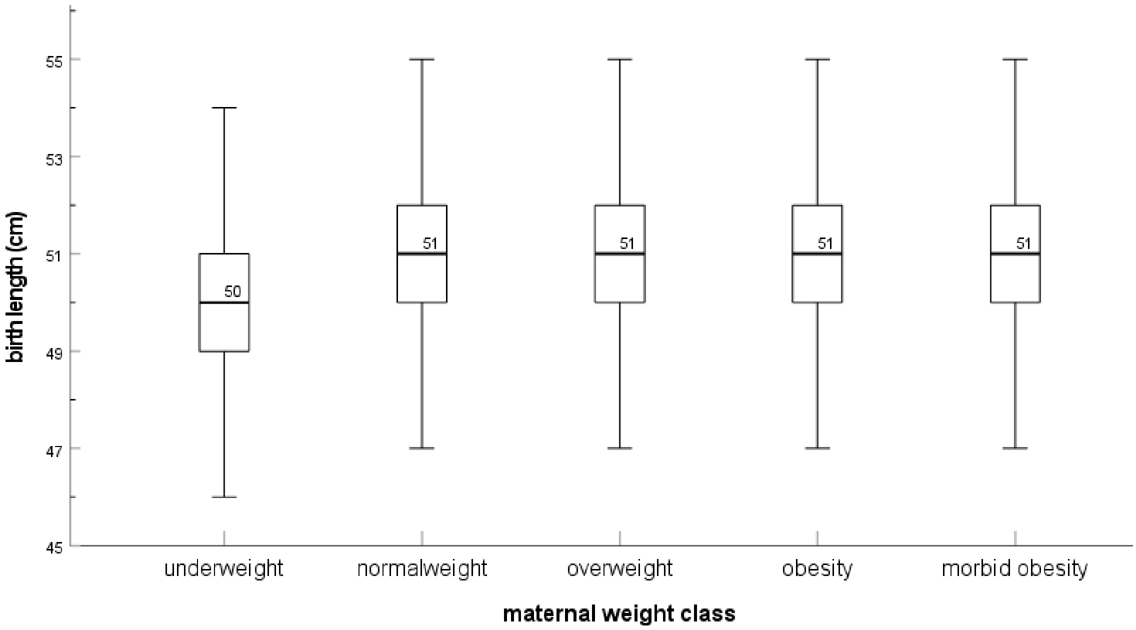

Figure 3: Boxplots of birth length in each maternal weight class. The outliers and extreme values are not shown. The median of the birth length of new-borns of underweight women differs from all other groups.

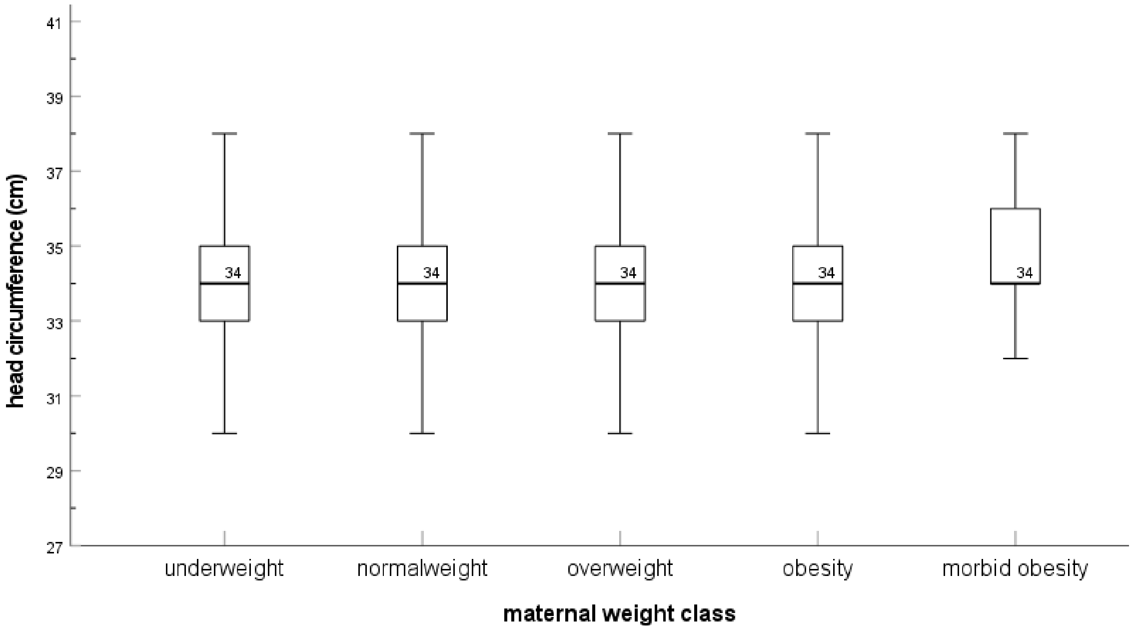

Figure 4: Boxplots of the new-borns head circumference in each maternal weight class. The outliers and extreme values are not shown. The medians and quartiles of the first four groups (underweight to obese) do not differ. The distribution of the new-borns of morbidly obese women is right skewed.

Risk for macrosomia among different weight classes

There is a clear relationship between the weight class of the woman and the risk of macrosomia in the new-born. The risk for macrosomia increases with increasing maternal weight class, see table 4. While the new-borns of underweight women have a significantly lower risk of macrosomia than those of normal-weight women, neonates of overweight women have a 1.37-fold higher risk of macrosomia compared to those of normal-weight women. The effect is even more pronounced in the new-borns of obese and morbidly obese women: Here, the risk of macrosomia increases by a factor 1.88 and 2, respectively, compared to children of normal-weight women.

table 4: Risk for macrosomia among different weight classes compared to normal weight women. The risk for macrosomia increases continuously with increasing maternal weight class.

weight class	***p* value**	**risk ratio**	**95% confidence-interval**	
			lower value	**upper value**
underweight	<0.001	0.446	0.327	0.608
overweight	<0.001	1.372	1.212	1.554
obesity	<0.001	1.877	1.623	2.171
morbid obesity	<0.001	2.006	1.376	2.925

Association between pH value of umbilical cord blood and maternal obesity

Arterial umbilical cord blood

In the scatterplot below (Figure 5) the pH values of the arterial cord blood are plotted in relation to the maternal BMI before pregnancy. The regression line has a negative slope, indicating that the pH value of the arterial cord blood decreases with increasing maternal BMI ($B = 7.258$, $\beta = -0.066$, $p < 0.001$, $R^2 = 0.004$). Although highly significant, the coefficient of determination is relatively low. Only 0.4% of the variance of the pH value can be explained by the maternal BMI.

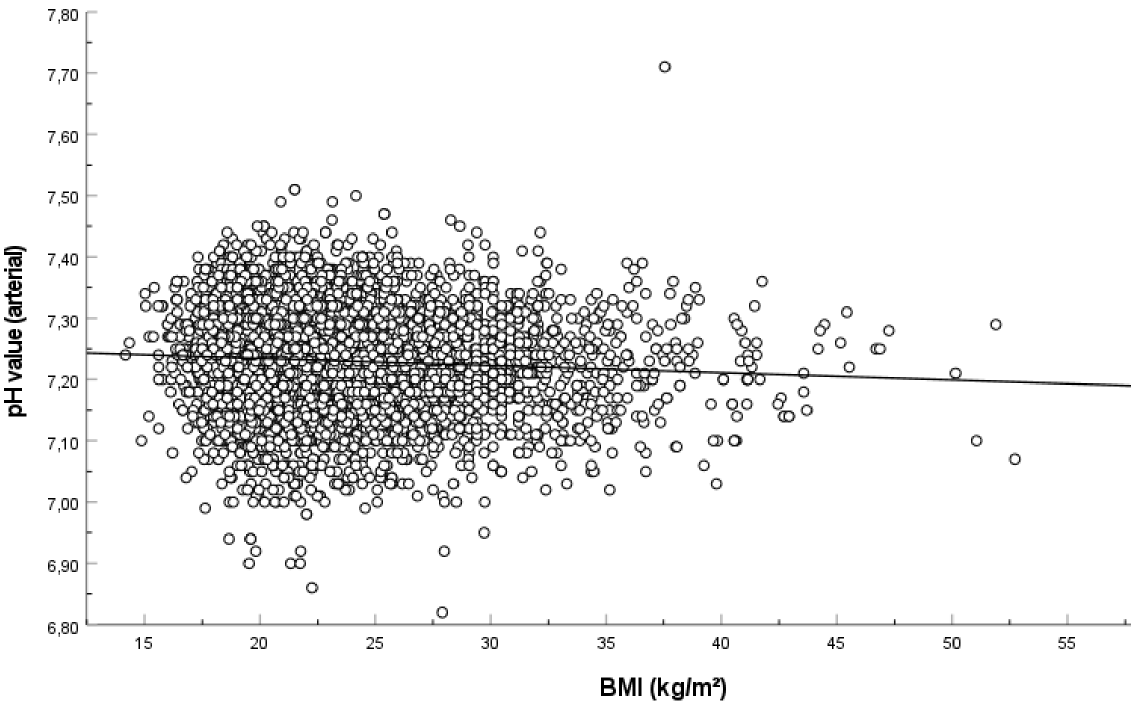

Figure 5: Scatter plot of maternal BMI and pH value of arterial umbilical cord blood. The mother's BMI before pregnancy is plotted on the x-axis, the pH values of the arterial umbilical cord blood on the y-axis. As the regression line shows, the pH value of the arterial cord blood decreases with increasing maternal BMI.

The graph below (Figure 6) shows the pH values of the umbilical arterial blood for each maternal weight class. It shows the trend that as the weight class of the mother increases, there is a decrease in the pH value of the arterial blood of the umbilical cord. While the median of pH value in underweight women is 7.24, that in morbidly obese women is only 7.21.

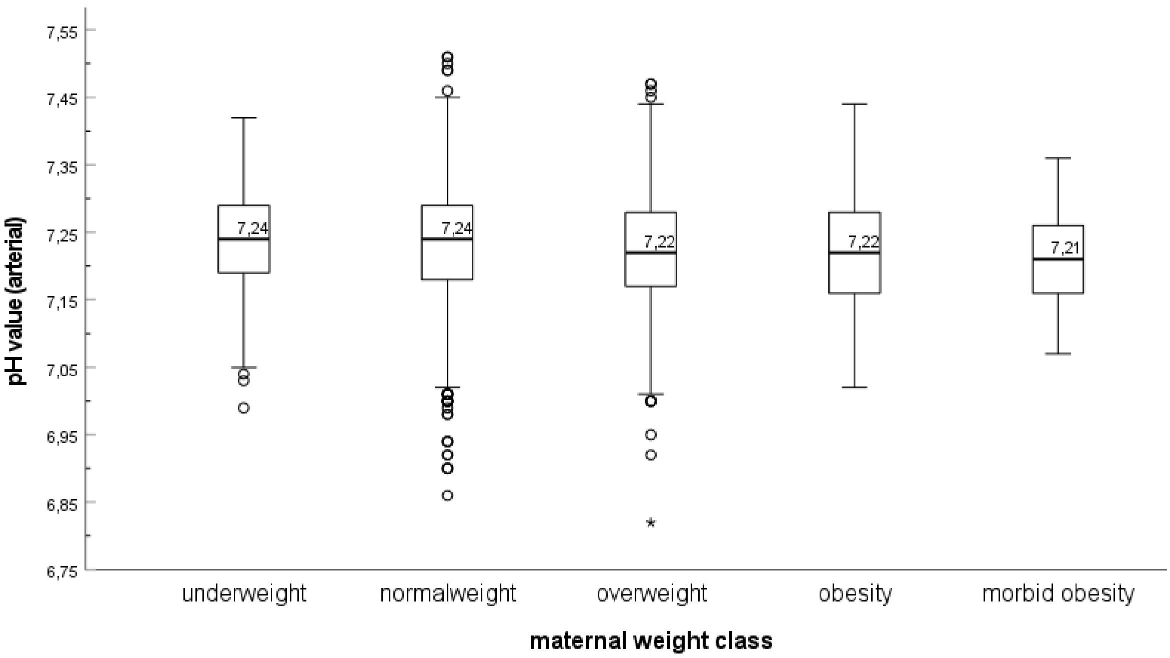

Figure 6: Boxplot of pH value of arterial umbilical cord blood and maternal weight class. The pH values tend to become lower with increasing maternal weight class.

A Kruskal Wallis *H* test is performed to test for possible significant differences between maternal weight-classes in the pH value of the arterial cord blood. The result is highly significant ($p<0.001$, $H = 26.601$). Subsequent Bonferroni corrections show that obese women differ significantly from underweight and normal weight women ($p=0.005$ and $p=0.011$, respectively). In addition, overweight women also differ significantly from underweight and normal weight women ($p=0.012$ and $p=0.014$, respectively). All other groups do not differ significantly from each other in terms of pH value of the arterial cord blood.

The mean, median, quartiles and standard deviation of the arterial blood pH values and the corresponding sample size per maternal weight class are shown in table 5. The sample size differs strongly between the groups.

table 5: Sample size, mean, median and standard deviation and Quartiles of the pH value (arterial cord blood) of each maternal weight class. The mean pH value of the arterial umbilical cord blood decreases with increasing weight class of the mother.

			pH value (arterial)		
Maternal weight class	**N**	**mean**	**median**	**SD**	**Q1/Q3**
underweight	411	7.24	7.24	0.075	7.19/7.29
normal weight	3706	7.23	7.24	0.081	7.18/7.29
overweight	942	7.22	7.22	0.083	7.17/7.28
obesity	448	7.22	7.22	0.085	7.16/7.28
morbid obesity	47	7.21	7.21	0.068	7.16/7.26
total	5554	7.23	7.23	0.081	7.18/7.29

Venous umbilical cord blood

The pH values of the venous cord blood in relation to the maternal BMI before pregnancy are shown in Figure 7. Although the regression line has a slightly negative slope, there is no clear trend between the pH value of the venous cord blood and maternal BMI (B = 7.308, $\beta = -0.031$, $p = 0.023$, $R^2 = 0.001$).

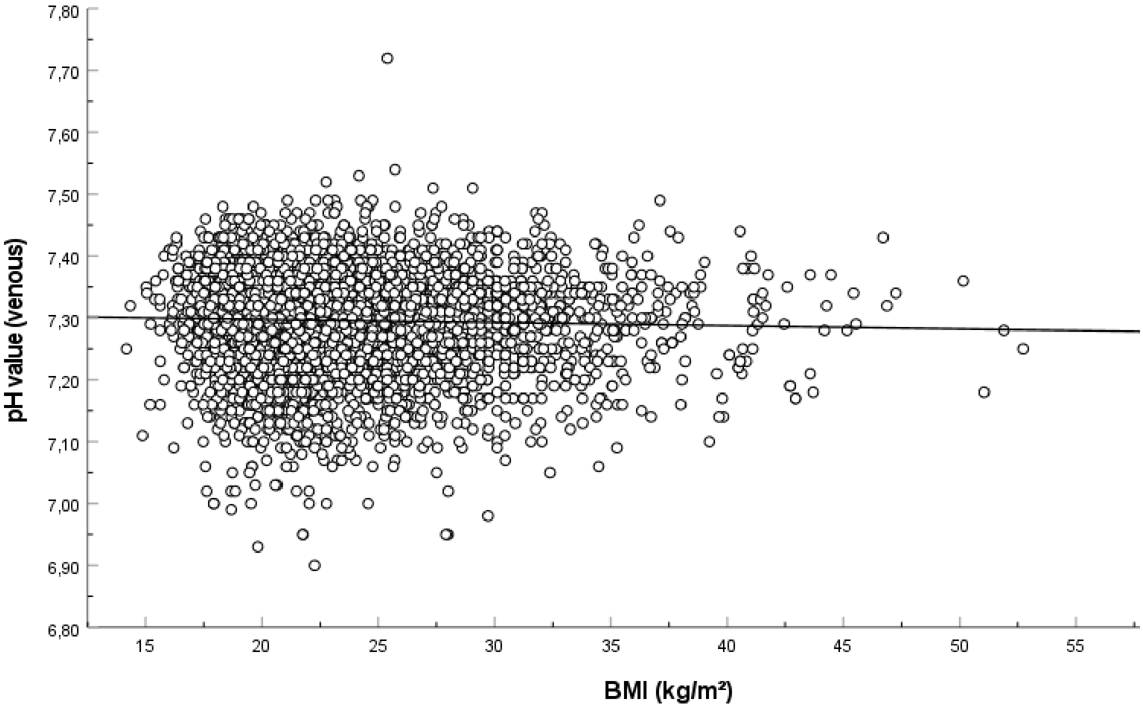

Figure 7: Scatter plot of maternal BMI and pH value of venous umbilical cord blood. The mother's BMI before pregnancy is plotted on the x-axis, the pH values of the venous umbilical cord blood on the y-axis. The regression line shows that as maternal BMI increases, the pH value of the venous cord blood decreases slightly.

A Kruskal Wallis *H* test is then performed to test for an association between maternal weight class and pH value of venous cord blood. The test has a significant result (p=0.042, H=9.917), however, subsequent post hoc tests according to Bonferroni show no significant differences between the groups. The plot below illustrates the relationship between the pH value of the venous umbilical cord blood and maternal weight class. Although the differences between the groups are not significant, there is still a trend apparent that the pH value of the venous cord blood decreases with increasing maternal weight class. Thus, the median pH value in underweight women is 7.31, while that of morbidly obese women is 7.29, see Figure 8.

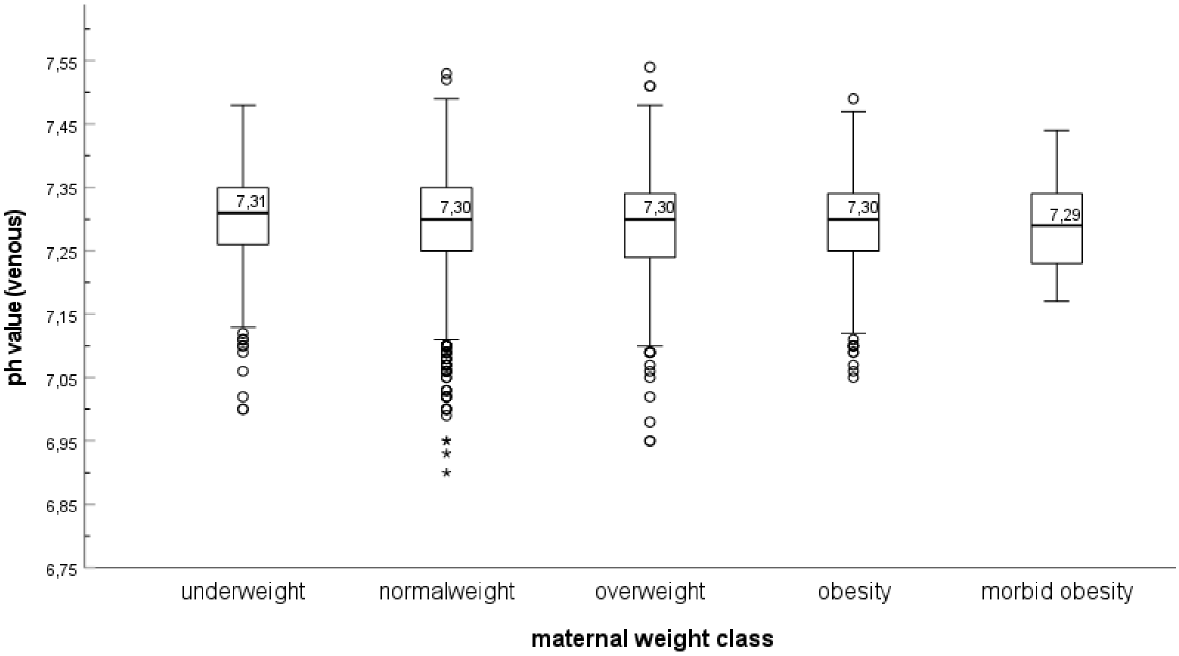

Figure 8: Boxplot of pH value of venous umbilical cord blood and maternal weight class. Although not significant, the pH values tend to decrease with increasing maternal weight class.

The following table (table 6) shows the mean, median, quartiles and standard deviation of the venous blood pH values and the corresponding sample size per maternal weight class. There is a strong difference in the sample size between the groups.

table 6: Sample size, mean, median and standard deviation and Quartiles of the pH value (venous cord blood) of each maternal weight class. The mean pH value of the arterial umbilical cord blood decreases with increasing weight class of the mother.

		pH-value (venous)			
Maternal weight class	**N**	**mean**	**median**	**SD**	**Q1/Q3**
underweight	405	7.30	7.31	0.078	7.26/7.35
normalweight	3648	7.30	7.30	0.075	7.25/7.35
overweight	925	7.29	7.30	0.080	7.24/7.34
obesity	445	7.29	7.30	0.077	7.25/7.35
morbid obesity	47	7.29	7.29	0.072	7.23/7.34
total	5470	7.30	7.30	0.076	7.25/7.35

Comparison of maternal weight classes and miscarriage rates

A significant relationship ($\lambda=35.120$, df=4, $p<0.001$) can be found between the history of miscarriages and maternal weight class, see table 7. The risk of a miscarriage increases with increasing BMI weight class of the mother.

table 7: Cross table of maternal weight class and the occurrence of at least one miscarriage

		Maternal weight class				
		underweight	**normalweight**	**overweight**	**obesity**	**morbid obesity**
No miscarriage	*N*	671	6583	2093	1096	108
	Expected N	654.2	6458.6	2171.6	1136.0	130.6
	Std. residuals	0.7	1.5	-1.7	-1.2	-2.0
miscarriage	*N*	281	2815	1067	557	82
	Expected N	297.8	2939.4	988.4	517.0	59.4
	Std. residuals	-1.0	-2.3	2.5	1.8	2.9

Pairwise comparisons between normal weight women with all other groups are necessary to determine the risk of a miscarriage in each case, see table 8. Underweight and normal weight women do not differ significantly in miscarriage risk. Between overweight and normal-weight women, however, significant differences can already be seen with regard to the miscarriage risk. The risk of miscarriage is increased by about 1.2 times in overweight and obese women compared to normal weight women. The effect is even stronger in morbidly obese women, with a 1.8 time higher risk of miscarriage compared to normal weight women.

table 8: Risk for miscarriage among different weight classes compared to normal weight women

Weight class	P value	Risk ratio	95% confidence-interval	
			Lower value	**Upper value**
underweight	0.779	0.979	0.846	1.133
overweight	<0.001	1.192	1.094	1.299
obesity	0.002	1.188	1.063	1.328
morbid obesity	<0.001	1.776	1.328	2.374

The ratios of the occurrence of at least one miscarriage to no miscarriages per maternal weight class are shown in Figure 9. As weight class increases, the risk of at least one miscarriage increases. There are no significant differences between underweight and normal weight women (λ= 0.079, p=0.779) and overweight and obese women (λ= 0.002, p=0.961) with regard to the risk of a miscarriage.

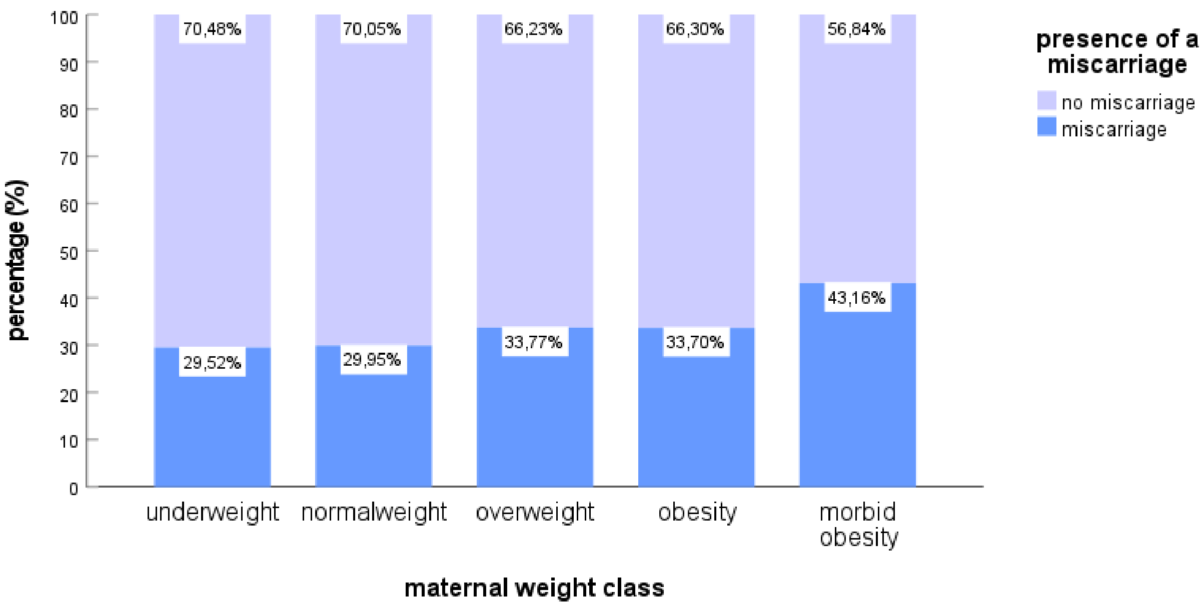

Figure 9: Difference of gravida and para as an indicator of miscarriage rate. The percentages of miscarriages to no miscarriages per maternal weight class are shown. The incidence of at least one miscarriage increases with increasing maternal weight class. There is an increased risk of a history of at least one miscarriage in morbidly obese women compared to all other weight classes.

Taking into account not only whether there has been at least one miscarriage or not, but also considering the number of miscarriages, distinctions between maternal weight groups can also be seen. The mean values of the miscarriage rate for all maternal weight groups are shown in table 9. The mean value increases with increasing weight class of the mother. A Kruskal Wallis *H* test and Bonferroni post hoc tests are used to test for alterations in miscarriage rate between maternal weight-classes. A significant relationship between maternal weight class and miscarriage rate is detected ($p<0.001$ $H = 48.362$, d.f. = 4). In general, women of higher weight classes have significantly more miscarriages than those from lower weight classes. Post hoc tests show that underweight and normal weight women do not differ significantly in the miscarriage rate. Furthermore, overweight and obese women also do not differ significantly from each other and there are no significant differences between underweight and overweight, and between underweight and obese women in terms of miscarriage rate ($p = 0.062$, and $p = 0.073$, respectively). All other groups differ significantly from each other.

table 9: Sample size, mean, median, standard deviation, and quartiles for the difference between gravida and para for all maternal weight classes.

Weight class	N	mean	median	SD	Q1/Q3
underweight	952	0.42	0	0.770	0/0
normalweight	9396	0.43	0	0.827	0/0
overweight	3160	0.51	0	0.893	0/0
obesity	1653	0.55	0	0.995	0/0
morbid obesity	190	0.76	0	1.091	0/0
total	15351	0.47	0	0.863	0/0

Association between maternal weight class and mode of delivery

To determine a possible association between maternal pre-pregnancy weight status and mode of delivery, a Chi² test is used. A significant relationship can be found between maternal weight class and mode of delivery ($\lambda = 81.777$, d.f. = 12, $p<0.001$). It can be seen that obese and morbidly obese women in particular have more caesarean deliveries (primary and secondary) and fewer vaginal, spontaneous deliveries than expected, see table 10.

table 10: Cross table of maternal weight class and mode of delivery. There is a significant relationship between mode of delivery and maternal weight class before pregnancy ($\lambda = 81.777$, d.f. = 12, $p<0.001$)

Weight class		Birth mode			
		spontaneous	VE / Forceps	primary section	secondary section
	N	778	51	57	66
underweight	*Expected N*	749.7	50.7	68.1	83.5
	Std. residuals	1.0	0.0	-1.4	-1.9
	N	7500	521	613	764
normalweight	*Expected N*	7400,6	500.7	672.7	823.9
	Std. residuals	1.2	0.9	-2.3	-2.1
	N	2449	168	237	306
overweight	*Expected N*	2488.4	168.4	226.2	277.0
	Std. residuals	-0.8	0.0	0.7	1.7
	N	1237	68	166	182
obesity	*Expected N*	1301.7	88.1	118.3	144.9
	Std. residuals	-1.8	-2.1	4.4	3.1
	N	126	10	26	28
morbid obesity	*Expected N*	149.6	10.1	13.6	16.7
	Std. residuals	-1.9	0.0	3.4	2.8
total	*N*	12090	818	1099	1346

Risk-ratios are calculated to clarify to what extent the risk of a secondary caesarean section is increased or decreased in the different weight classes compared to normal-weight women. In overweight, obese and morbidly obese women, the risk of secondary caesarean section increases continuously from 1.2 times higher risk in overweight women to 2.2 times higher risk in morbidly obese women compared to normal weight women, see table 11. There is no significant difference between underweight and normal weight women in terms of the risk of secondary caesarean deliveries.

table 11: Risk for secondary caesarean section among different weight classes compared to normal weight women

Weight class	P value	Risk ratio	95% confidence-interval	
			Lower value	Upper value
underweight	0.171	0.833	0.641	1.082
overweight	0.004	1.227	1.066	1.411
obesity	<0.001	1.444	1.216	1.716
morbid obesity	<0.001	2.182	1.439	3.308

Figure 10 illustrates the extent of maternal weight class on mode of delivery, only spontaneous births and secondary caesarean sections are shown. It shows a clear trend that as maternal weight class increases, the percentage of spontaneous vaginal deliveries decreases, and correspondingly, the percentage of secondary caesarean delivery rates increases.

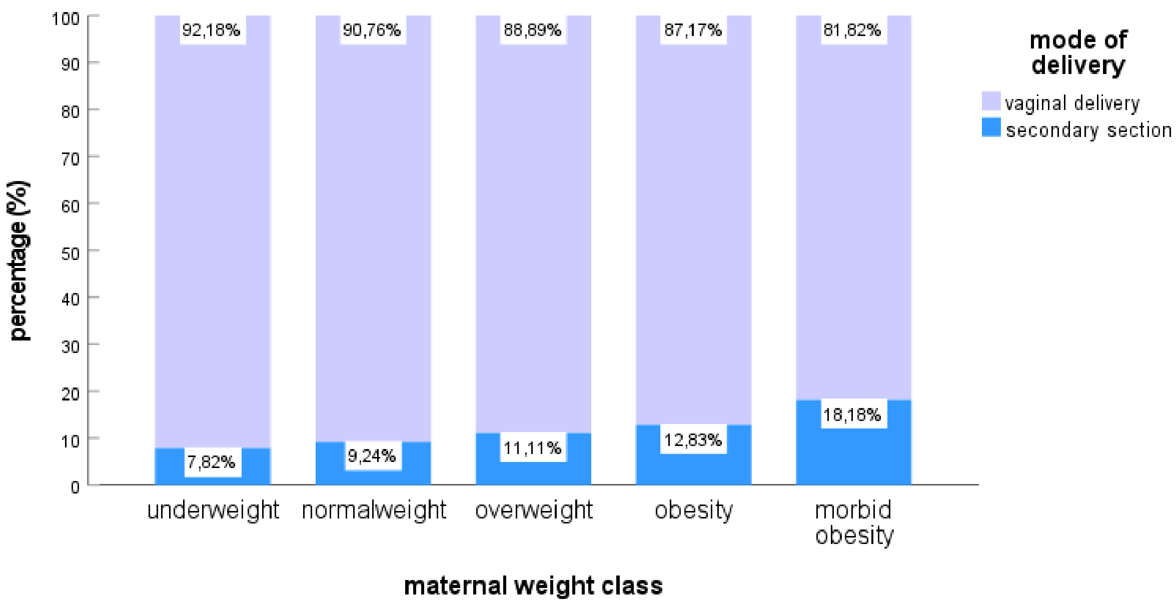

Figure 10: Percentage of vaginal deliveries and secondary caesarean deliveries per maternal weight class. Secondary caesarean delivery rates increase in frequency with increasing weight class.

A binary logistic regression model is calculated to show the independent effects of maternal BMI on the mode of delivery. It shows that maternal BMI has an independent significant effect (p<0.001) on the occurrence of secondary caesarean sections. In addition to the BMI, also weight gain during pregnancy (in percentages), maternal age, and neonatal head circumference have a positive, significant and independent effect on secondary caesarean section rates.

Maternal stature as well as birth weight are significantly, negatively associated with the caesarean section rate.

table 12: Binary logistic regression. All variables have a highly significant and independent effect on the rate of secondary caesarean sections.

Independent variables	B (SE)	*p* value	Exp(B)	95% confidence interval Lower value	95% confidence interval Upper value	R^2
Maternal BMI	0.080 (0.007)	<0.001	1.083	1.069	1.098	0.073
Weight gain (%)	0.032 (0.003)	<0.001	1.033	1.026	1.040	
Maternal age	0.046 (0.006)	<0.001	1.047	1.036	1.059	
Maternal stature	-0.042 (0.005)	<0.001	0.959	0.950	0.969	
Birth weight	-0.001 (<0.001)	<0.001	0.999	0.999	0.999	
Head circumference	0.188 (0.024)	<0.001	1.207	1.151	1.267	

Occurrence of secondary caesarean section as dependent variable and maternal BMI, weight gain during pregnancy as percentage of pre-pregnancy body weight, age, stature, birth weight and head circumference as independent variables

Discussion

Obesity figures are rising rapidly and have achieved pandemic proportions (WHO, 2020). The rising numbers are particularly fatal among women of reproductive age, as obesity before and during pregnancy is associated with many complications for mother and child (Gaillard et al., 2017; Sebire et al., 2001). In this study, the focus is on neonatal parameters, cord blood pH values, miscarriage rate, mode of delivery and the respective effect of maternal obesity on each of them.

The first hypothesis of neonatal parameters being related to maternal BMI could be confirmed and verified. Considering birth length, birth weight, and head circumference, it is evident that as maternal pre-pregnancy BMI weight class increases, the neonate has significantly larger dimensions. This is largely consistent with previous literature (Athukorala et al., 2010; Jolly et al., 2003; Kirchengast, 2019). Figure 2 shows a slight decrease in median values of the birth weights of new-borns between obese (3510 g) and morbidly obese (3495 g) women. However, this difference is not significant. Nevertheless, previous studies have shown that maternal obesity and especially morbid obesity can not only cause relatively large new-borns and macrosomia, but can also be responsible for low birth weight and even foetal growth retardation. Maternal obesity may thus have multidirectional and opposing effects on birth weight (Lewandowska, 2021). In this sample, the risk of macrosomia increases with increasing weight class. While the risk for macrosomia is 1.4 times higher in overweight women than in normal-weight women, the risk in obese women is almost twice as high compared to normal weight women.

The precise mechanisms of how maternal obesity affects foetal growth are not yet fully understood. It cannot be explained by classical Mendelian laws because maternal obesity has stronger effects on the child than paternal obesity (Whitaker et al., 2010). It is certain that maternal obesity exposes the embryo to a different hormonal and external environment. The complex interaction of environment and genes can lead to abnormal growth in the foetus and affects organ formation considerably (Tenenbaum-Gavish & Hod, 2013). Macrosomia, in turn, is associated with several complications, including increased risk of caesarean section, extended stay in hospital, chorioamnionitis (Stotland et al., 2004) and many others.

Not only can neonatal dimensions be affected by maternal obesity before and during pregnancy, but other characteristics, such as cord blood pH values, can vary with maternal weight status (Johansson et al., 2018). The pH value serves as an indicator of foetal acidosis or oxygen deficiency during birth, respectively (Malin et al., 2010). However, the hypothesis that maternal

BMI is related to cord blood pH values and thus to neonatal oxygen supply during birth could only be partially verified. While arterial cord blood pH values are significantly associated with maternal weight status, venous cord blood pH values do not provide significant results in pairwise comparisons of maternal weight classes. Previous studies have shown that overweight and obesity are associated with foetal acidosis. One indicator of such oxygen deficiency during birth is the pH value of the umbilical cord blood (Johansson et al., 2018). For correct and adequate testing of the hypothesis that cord blood pH value is associated with maternal weight status, some additional exclusion criteria were taken for the analysis of pH values. First, only pH values >6.4 were taken into account, since lower values are more likely to be erroneous. Secondly, only vaginal births and no preterm births were included, since caesarean sections or preterm births could be the actual reasons for oxygen deficiency and thus for a low pH value of the umbilical cord blood. In addition, only primiparous women were included in order to obtain a sample that was as uniform as possible, as foetal acidosis depends on parity (Johansson et al., 2018).

Studying the pH values of umbilical cord blood, the results of the individual previous studies are very different and sometimes even contradictory (Malin et al., 2010). This is mainly due to the following reasons: On the one hand, different studies use different thresholds for pH values. The question, which pH cut-off value to use is not obvious and straightforward. It has not been uniformly defined in previous studies. While many studies consider a pH value of <7.2 to be critical, others assume an increased risk for the new-born at a threshold value of pH <7.0 (Mogos et al., 2019; Yeh et al., 2012). Yeh et al. (2012) suggest that a pH value between 7.26 and 7.30 is ideal, a higher value not necessarily being better. Within this range the risk of negative effects for the baby is lowest. Therefore, many studies dealing with oxygen deficiency, pH values of umbilical cord blood and their consequences come to different, partly contradictory results and thus also to different conclusions. On the other hand, different studies sometimes use different variables, for example, arterial and venous umbilical blood (Malin et al., 2010). Therefore, standardization of the limits of pH values and the use of the same standards and variables would be an important step to counteract these inconsistencies and to achieve consistent results between studies.

In this study the association of cord blood pH value and maternal weight classes is only partially consistent with previous literature. Although the regression line between (arterial) pH values and maternal BMI shows a negative slope, indicating a negative correlation between the two variables, the corresponding R^2 is relatively small (0.004), maternal BMI can explain only a very small amount of variance in pH values. Dividing BMI again into the respective weight categories there is a tendency for median pH values to decrease with increasing maternal weight categories, with normal weight women having a median of 7.24 and morbidly obese women having a median of 7.21. In this study, both obese and overweight women differ significantly from normal-weight and underweight women in arterial cord blood pH values. The question arises why, contrary to previous literature, like Johansson et al. (2018), the other groups do not differ significantly from each other with respect to this characteristic in this sample. A possible reason for that could be the small sample sizes of some weight classes. Especially the group of morbidly obese women (N=47) is strongly underrepresented in this study.

Looking now at the pH values of the venous cord blood, there are no significant differences at all in the pairwise comparisons between the groups. Although the same trend as in the analysis of the pH value of the arterial blood is observed, namely a decrease of the pH value with increasing maternal weight class, see Figure 8, these results are not significant. The sample sizes were not markedly different from those of the arterial blood analysis. Accordingly, venous cord blood is not particularly suitable for determining the health status or oxygen supply respectively of the neonate during birth. However, the pH value of the arterial cord blood on the other hand has been established as the best indicator of foetal acidosis (Blickstein & Green, 2007). Other variables and measurements such as venous cord blood pH values only provide additional information, but should not be used alone to determine the health status of the new-born. The pH values of the arterial cord blood correlate best with the APGAR scores and reflect the health status of the new-born (Thorp et al., 1989). Furthermore, it can be seen that the statistical approach can also lead to different interpretations. In this specific case, boxplots show a clear trend towards decreasing pH values with increasing maternal weight class, whereas correlation and regression analysis do not show such a clear trend. Therefore, a clear definition and/or standardization of the studies are essential.

In the next step, it was tested whether the history of miscarriages was related to maternal weight class. The hypothesis that women who were obese at the time of data collection were more likely to have miscarriages was verified. Previous studies have shown that with higher maternal BMI, the risk of miscarriage increases (Ghimire et al., 2020). Since in this sample the difference between the number of pregnancies and that of births was used as an indicator of the miscarriage rate, the time of the miscarriage and therefore the weight status of the women at that time are not known. Instead, simplified, the history of miscarriages of the women was compared between the different current weight categories. A significant association between weight class and history of miscarriage was detected ($p<0.001$), with overweight and obese women having experienced more miscarriages than normal weight women. The risk of ever having suffered a miscarriage is 1.2 times higher in overweight women and 1.8 times higher in morbidly obese women than in women of normal weight. It could be shown that normal-weight women differed significantly from all groups (except from underweight women) on this characteristic. This means that as the weight class increases, the number of miscarriages also increases. All other groups are not significantly different from each other, probably again due to the smaller sample sizes.

A direct causality between obesity and increased miscarriage rate cannot be concluded due to the lack of data on weight status at the time of miscarriage in this study. Thus, other factors may be responsible for the statistical association found here. Women often struggle with anxiety, depression and guilt after a miscarriage (Adolfsson et al., 2004). Since depression and obesity show a clear correlation (Jantaratnotai et al., 2017), theoretically depression as a consequence of a previous miscarriage could have also led to obesity, thus to this association. Nevertheless, a number of studies show a clear and definite link between obesity and an increased risk of miscarriage (Ghimire et al., 2020). The consequences of miscarriages can be very diverse and in some cases severe. In addition to the already mentioned depressions into which women can fall, studies also show that after a miscarriage, women are at higher risk for complications, like preterm birth, low birth weight and even neonatal death in their following pregnancies (Bhattacharya & Bhattacharya, 2009; Makhlouf et al., 2014). Overweight and obesity clearly pose an increased risk for miscarriage, although obesity is, unlike other risk factors such as increased maternal age (Khalil et al., 2013), preventable. Problem-focused approaches and interventions for sustainable weight loss in overweight women of reproductive age are needed to reduce miscarriage rates in a long-term manner.

Finally, the association between birth mode and maternal weight status was examined. Considering the association between mode of delivery and maternal obesity, the results of this study are largely consistent with previous literature (Masoud et al., 2016; O'Dwyer & Turner, 2012). The hypothesis that birth mode is related to maternal weight status was verified. A significant relationship between maternal weight class and mode of delivery could be shown ($p<0.001$). It is particularly important to clarify to what extent maternal weight is related to secondary caesarean section rates. Secondary caesarean deliveries are those C- sections that are not planned and that require an acute change from a vaginal delivery to a caesarean section. Since secondary caesarean sections are acutely medically necessary interventions, those types of

C-sections are in the focus of this study. As maternal BMI increases, the secondary caesarean section rate also increases. It is particularly noticeable that the risk for a secondary caesarean section very strongly depends on the severity of obesity. While overweight women have a 1.2-fold higher risk and obese women a 1.4-fold higher risk, morbidly obese women already have more than twice the risk (2.1 fold higher) for being in need of a secondary caesarean section compared to normal weight women. This is a very abrupt increase in risk between obese and morbidly obese women. These results are roughly in line with the findings of Chu et al. (2007), although the calculated C-section risks of their study are even slightly higher.

As obesity rates rise in every age category at an alarming rate worldwide (*Obesity Update - OECD*, 2017; WHO, 2020), especially among young adults and women of reproductive age, C-section rates are also increasing (Weiss et al., 2004). In general, current trends and lifestyle changes in recent decades have led to an increase in secondary caesarean section rates. This includes not only rising obesity numbers, but also increased average maternal age and large weight gain during pregnancy (Kirchengast & Hartmann, 2019). Therefore these parameters must be controlled for before an independent effect of maternal weight status on caesarean section rates can be concluded. A binary logistic regression model shows an independent effect of BMI on the mode of delivery ($p<0.001$), respectively on the incidence of a secondary caesarean section.

The increasing caesarean section rates have several disadvantages and entail problems which should be discussed here. On the one hand, this is very stressful for the women themselves, since caesarean sections are routine but still serious surgeries, with many possible complications associated (van Ham et al., 1997). On the other hand, the increasing rates of caesarean sections also represent a burden for the health care system, as they are associated with high costs and effort (Gibbons et al., 2010). Surgeries like C-sections for severely obese individuals are a much greater expense for health care professionals and on average, obese individuals also require longer hospital stays (Heslehurst et al., 2008). In addition to financial factors, the rising caesarean section rates also have a strong influence on the well-being of mother and child. Surgeries of any kind, including C-sections, are a considerably higher risk in overweight and obese individuals than in normal-weight individuals (Ri et al., 2018). Especially in morbidly obese women, a caesarean section presents great technical difficulties, some of which can have severe life-threatening consequences (Whitty et al., 2007). The problems range from difficulty in anaesthesia, finding the epidural space, to difficult conditions in transporting patients and increased numbers of staff required (O’Dwyer & Turner, 2012). This causes another burden on the health care system. In order to achieve a sustainable reduction of the secondary caesarean section rate, i.e. the rate of those caesarean sections that are actually acutely medically necessary, a reduction in the obesity rate among women of childbearing age would be of major importance.

At the end of this work, the relevance of the whole thesis and topic will be summarized. Obesity has reached pandemic proportions. Nowadays, obesity can be found in all latitudes and cultures, with increasing tendency (Ritchie & Roser, 2017). For this reason, it is of utmost importance to intensively investigate the topic at all levels. More people now die from obesity than from undernourishment (WHO, 2020), and this despite the fact that overweight and obesity can be prevented. Every year, the disease claims hundreds of thousands of lives. It is estimated that overweight and obesity is the 5th largest cause of death, with at least 2.8 million people dying each year due to obesity (The European Association for the Study of Obesity, 2021). In particular, the number of overweight and obese individuals in young adulthood is steadily increasing (Poobalan & Aucott, 2016; Statistik Austria, 2015, 2020b). These are the people of reproductive age and especially young women are facing many problems in this respect. Maternal obesity before and during pregnancy can have fatal consequences for the mother, the child, as well as the health care system, as this work has already emphasized in detail. The consequences of maternal obesity can be far-reaching and can affect the child's health far into adulthood (Gaillard et al., 2017). This study shows once again how important obesity research is. It is not only the people that are affected by the disease, but the effects of obesity reach far into the next generation. Therefore, it is important to address the problem at all levels in order to counteract it. Effective prevention measures, like increasing education, communication and awareness of the problem in school as well as sustainable weight loss strategies towards a healthy weight should be developed and improved. The need for action on the part of politicians and decision-makers at national and international level is absolutely essential in this context.

Limitations

The limitations of this study should not go unmentioned. In the following, the use of BMI as a measure of weight status, advantages and especially disadvantages of this measure will be discussed. Then, the use of the difference between gravida and para as an indicator of miscarriage rate is addressed. Furthermore, it should be noted that no information is available on the socioeconomic status of the women. In addition to the undisputed biological effects of obesity on mother and child, the socioeconomic status could also have an independent influence on the development of the child.

Using the BMI as a measure of weight status

The BMI is a practical, widely used and accepted measure to evaluate weight status in adults. Nevertheless, the BMI has some limitations that cannot be ignored. Since BMI is only a weight to length measure and does not take body composition into account, no distinction is made between lean mass and fat mass. A person with a high muscle mass therefore also has a high BMI and might thus incorrectly be classified as overweight or even obese. Vice versa, the BMI of a person with high fat mass but low lean mass is also not sufficiently informative to a certain extent (Daniels, 2009). In addition, there is the phenomenon that people of different ethnicities also have different "cut-off values" for the BMI. For example, the probability of suffering from related diseases of a high BMI is increased in Asian ethnic groups at a lower threshold value than in other ethnic groups (Snehalatha et al., 2003). The mechanisms behind this fact have not yet been clarified completely. The question arises whether the BMI should be adapted considering different ethnic groups. However, this remains difficult, because it is hardly possible to assign people to a single ethnic group (Daniels, 2009).

Nevertheless, the BMI is a practical measure to determine the weight status because, unlike DEXA (=dual-energy X-ray absorptiometry), air displacement plethysmography and many other methods, its use is cheap, easy to survey, non-invasive and also safe. As alternatives, waist-to-height-ratios, waist-to-hip rations and bioelectric impedance analysis (BIA) are recommended, but more research is needed to establish these methods in clinical studies (Daniels, 2009). Additionally, studies have shown that BIA systematically results in lower fat mass values, depending on gender and weight status, than DEXA (Völgyi et al., 2008).

Gravida-Para difference as indicator for miscarriages

The difference between the number of pregnancies and the number of actual births alone, of course, as an indicator of the miscarriage rate says nothing about intentional and wanted abortions. Since no information on wanted abortion rates is available, they cannot be considered in this analysis. Therefore, only the difference between gravida and para is used as an indicator for miscarriage.

Since abortions in Austria are not paid for by health insurance, there are also no reporting statistics on the total number of abortions. The summarized data of the different clinics lead to an estimated number of 30-35,000 abortions in Austria per year (Fiala & Schweiger, 2016). However, these figures do not provide any information about who (in terms of socioeconomic status) is more likely to have an abortion.

Data from Sweden show that better educated Swedish women are less likely to have abortions than less educated women. In addition, a cultural effect could be shown, as this correlation could not be shown in Pakistani women living in Sweden (Eskild et al., 2007). If we infer socioeconomic status directly from the level of education, and obese women have a lower status on average (Lampert, 2010), there could be a correlation between wanted abortions and obesity in this respect. Since socioeconomic status was not taken into account in this study, no more explicit statements on this topic can be made and it would be speculative to conclude a correlation.

However, if the difference in the number of pregnancies and the number of births is used as an indicator of the miscarriage rate, there is another limitation that has to be taken into account. Only the women's current weight status is known, not their weight status at the time of the miscarriage. Therefore, only statements about the history of miscarriages per current maternal weight class can be made in this study. However, as can be seen in the results, a trend toward a higher miscarriage rate with higher maternal weight class can still be detected. Apart from these limitations, the difference between gravida and para is an easy way and quickly calculated indicator for miscarriages.

No information about socioeconomic status

No data on income, education, marital status, or any other indicator for socioeconomic status are available in this study. Therefore, these parameters cannot be considered in this master thesis. In general, status and social standing have an important impact on people's health. For example, lower status affects psychosocial health, risky behaviours, health awareness and preventive medical check-ups (Turrell & Mathers, 2000). In addition, differences in smoking behaviour and amount of physical activity were found between high and low status individuals, with lower status individuals smoking more and exercising less at the same time. These effects were found in both men and women (Lampert, 2010). Thus, there is an imbalance in mortality between the higher and lower social classes (Turrell & Mathers, 2000). Obesity and overweight in particular show a strong association with status and are major contributors to the disparity in mortality between socially lower and higher classes (Pigeyre et al., 2016). Status often has a different effect on men and women and depends on whether the country is developing, emerging or developed. Since food is still unfortunately often a scarcity in developing countries, obesity tends to be associated with higher socioeconomic status. In developed societies, however, the trend is the opposite: here women of lower status are often the ones affected by obesity (Sobal & Stunkard, 1989). For men, there seem to be partly opposite trends (Newton et al., 2017).

However, what are the underlying reasons for these disparities in weight between socially higher and lower individuals? Here it is important to distinguish between proximate, immediate reasons and ultimate, evolutionary reasons. Looking at proximate causes, the focus is primarily on two hypotheses: first, the availability of healthy food: Neighbourhoods with lower socioeconomic status are more likely to offer unhealthy food and fast food, while socially higher neighbourhoods offer healthier food choices. However, this hypothesis does not fully explain why socioeconomically lower people are more likely to choose energy-dense, unhealthy foods. Second, the price of healthy food: Healthy food is often more expensive than unhealthy food, which is why lower-status people are also more likely to reach for cheaper, unhealthier foods, regardless of availability (Caldwell & Sayer, 2019). However, even this hypothesis is insufficient and would not explain why additional resources/money provided to people of lower status leads to increased energy intake and not, as expected, to a reduction and consumption of healthier foods (Leroy et al., 2013). Additionally, it was found that socially underprivileged individuals tend to eat larger portions, eat uncontrollably, or eat late at night (Pigeyre et al., 2016).

However, just as important as understanding the proximate causes of higher obesity rates in socially lower classes, is, understanding the adaptation value and ultimate causes. Humans have always had to struggle with shortages of resources in the course of evolution. Therefore, behavioural changes are induced and fat accumulation is stimulated when the environment demands it. Furthermore, humans have a social structure that is unique in the animal kingdom and is crucial for food procurement. A loss of the social system would be followed by a loss of resources and energy supply (Caldwell & Sayer, 2019). It is therefore assumed that socially lower individuals tend to increase energy intake, out of the initial fear losing their social system and thus also of losing food supply (Neuberg & Kenrick, 2018).

Because weight status is so closely related to socioeconomic status, the lack of information on socioeconomic status is a major limitation of this study. To even out the differences between individuals of higher and lower socioeconomic status, politicians are required to act. Strategies should be developed to offer healthy food at a lower price and at the same time make unhealthy food accordingly more expensive (Inglis et al., 2005). Nevertheless, many previous studies show that the negative effects of maternal obesity during pregnancy on the new-born are independent of socioeconomic status (Gaillard et al., 2017). Therefore, it still makes sense to examine the relationships between maternal obesity and neonatal parameters, even without information on social status.

Conclusion

In conclusion, obesity during pregnancy is associated with many problems. These include acute birth complications (Araujo Júnior et al., 2017; O'Dwyer & Turner, 2012), as well as far-reaching long-term consequences for mother and child (Aviram et al., 2011; Gaillard et al., 2017; Sanchez et al., 2018). The health care system, the labour market, and the economy in general are also severely impacted by the continuing rise in obesity rates, especially among women of reproductive age (Hackl et al., 2010; Lindeboom et al., 2010). In this work, it was shown that with increasing maternal BMI, neonatal parameters are strongly influenced. Head circumference, birth weight and birth length increase significantly with increasing maternal weight class ($p<0.001$). In addition, it is shown that the pH value of the umbilical cord blood also depends on the maternal BMI. While the pH value of the venous cord blood shows no meaningful differences between the maternal weight classes, the values of the arterial blood differ significantly between the maternal BMI weight classes. Overweight and obese women differ significantly from underweight and normal weight women with respect to the pH value of the arterial cord blood ($p<0.02$, each). This work also demonstrates that the history of miscarriages depends on the current maternal BMI. A highly significant association ($p<0.001$) was found between the history of miscarriages and maternal weight class. The risk of having experienced at least one miscarriage is 1.2 times higher in overweight women and 1.8 times higher in morbidly obese women compared to normal weight women. In addition, a relationship was found between the mode of delivery and maternal weight class. As maternal weight class increases, the risk of being in need of a secondary caesarean section increases. Morbidly obese women have a 2.1-fold higher risk of needing a secondary caesarean section than normal-weight women. The effect was independent of maternal age and height, as well as birth weight and head circumference of the child.

Obesity rates are rising at an alarming rate (WHO, 2020), especially among young adults. Because the effects of maternal obesity before and during pregnancy are so pervasive, obesity in women of reproductive age in particular is a major concern (Anderson et al., 2003; Hillemeier et al., 2011). It is therefore of extreme importance to address the issue at all levels. This includes prevention strategies as well as weight loss measures that help overweight and obese people to sustainably achieve a healthy body weight. To do this, the problem must be considered in its entirety and not at the level of the individuals themselves (Harvard T.H. Chan, 2012). Here, it is up to decision-makers to act. Effective measures should be taken by politicians, like stricter advertising rules, especially for products consumed by children, price regulation such as a sugar tax, more awareness and education in schools, etc. (Duffey et al., 2010; Grogger, 2017; *Obesity Update - OECD*, 2017). More than just bold actions are needed to get a complex phenomenon like obesity under control.

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Abstract

In the last decades the obesity rate increased enormously and young women of reproductive age in particular are increasingly suffering from overweight or obesity. This creates a major problem, as obesity during pregnancy is associated with many complications, such as a higher rate of caesarean sections. The aim of this master thesis is to investigate the effects of maternal obesity on neonatal parameters, birth mode and miscarriage rate. It will be analysed whether there are differences in these parameters between women of different weight classes and their new-borns respectively. The sample includes singleton births of 15404 women, aged between 13 and 45.5 years. The births took place from 2009 to 2019 at the public hospital Sozial-medizinisches Zentrum Ost - Donauspital in Vienna. Neonatal parameters are birth weight (in g), birth length (in cm), and head circumference (in cm), as well as pH values of the arterial and venous umbilical cord blood. Maternal parameters include age (in years), height (in cm), body weight (in kg), and BMI (kg/m^2) at the beginning and the end of pregnancy. The duration of pregnancy, mode of delivery as well as the number of previous pregnancies and births are documented. It has been shown that birth length, birth weight and head circumference of the new-born increase on average with increasing maternal BMI. Furthermore, with increasing maternal weight class, there tends to be a decrease in the pH value of the umbilical cord blood, which is an indicator of the oxygen supply during birth. Additionally, obese women have a history of more miscarriages and need a secondary caesarean section more often than normal weight women do. Obesity before and during pregnancy has far-reaching consequences for the mother, the child, the health care system and thus for each and every one of us. It is now time to take the problem seriously and address it on a national and international level. This is where decision-makers must take effective countermeasures to sustainably reduce obesity rates.

Zusammenfassung

In den letzten Jahrzehnten hat sich die Adipositas-Rate explosionsartig vervielfacht und besonders junge Frauen im reproduktionsfähigen Alter leiden immer öfter an Adipositas. Das stellt ein großes Problem dar, da Adipositas während der Schwangerschaft mit vielen Komplikationen, wie zum Beispiel einer höheren Kaiserschnittrate, assoziiert ist. Ziel dieser vorliegenden Masterarbeit ist es, die Auswirkungen mütterlicher Adipositas auf die neonatalen Parameter, den Geburtsmodus sowie die Fehlgeburtenrate zu untersuchen. Es soll getestet werden, ob sich Frauen unterschiedlicher Gewichtsklassen und deren Neugeborene hinsichtlich dieser Parameter unterscheiden. Die Stichprobe umfasst Einlingsgeburten von 15404 Frauen, im Alter zwischen 13 und 45,5 Jahren. Die Entbindungen fanden von 2009 bis 2019 im Sozialmedizinischen Zentrum Ost - Donauspital in Wien statt. Zu den Neugeborenen-Parametern gehören das Geburtsgewicht (in g), die Geburtslänge (in cm) und der Kopfumfang (in cm), sowie der pH Wert des arteriellen und venösen Nabelschnurblutes. Die mütterlichen Parameter umfassen das Alter (in Jahren), die Körperhöhe (in cm), das Körpergewicht (in kg) sowie den BMI (kg/m^2) zu Beginn und am Ende der Schwangerschaft. Die Dauer der Schwangerschaft, die Art der Entbindung wie auch die Anzahl vorhergehender Schwangerschaften und Geburten wurden dokumentiert. Es konnte gezeigt werden, dass die Geburtslänge, das Geburtsgewicht und der Kopfumfang des Neugeborenen mit steigendem mütterlichen BMI durchschnittlich ansteigen. Außerdem kommt es mit zunehmender mütterlicher Gewichtsklasse tendenziell zu einer Verringerung des pH Wertes des Nabelschnurblutes, welcher ein Indikator für die Sauerstoffversorgung während der Geburt ist. Adipöse Frauen hatten in ihrer Vergangenheit mehr Fehlgeburten und brauchen öfter einen sekundären Kaiserschnitt als normalgewichtige Frauen. Adipositas vor und während der Schwangerschaft hat weitreichende Folgen für die Mutter, das Kind, das Gesundheitssystem und somit jeden von uns. Es ist längst an der Zeit sich des Problems auf nationaler- sowie internationaler Ebene anzunehmen. Hier sind Entscheidungsträger am Zug wirksame Gegenmaßnahmen zu treffen, um die Adipositas-Zahlen in den Griff zu bekommen.